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Normative Estimates of Class I Prices Across U.S. Milk Markets

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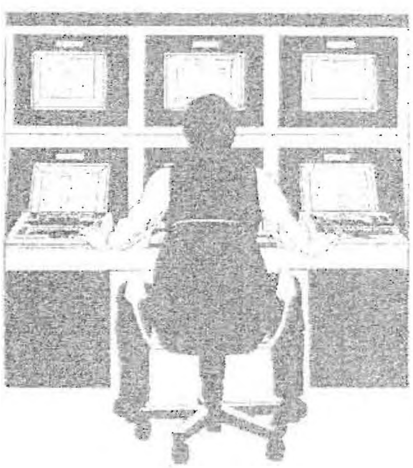

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Cornell Program on Dairy Markets and Policy

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PREFACE

The model results which are described in this document are the result of modeling research undertaken by the Cornell Program on Dairy markets and Policy (CPDMP). Over the years, contributions to this research have been made by a variety of people, not all of whom are authors of this paper.

The original concept for the model used in this analysis was developed by Dr. James Pratt (Senior Research Associate) and Dr. Andrew Novakovic (Director of the CPDMP and the E.V. Baker Professor of Agricultural Economics) in the early 1980s. As computational capacities increased, it became possible to expand the model's size and scope. The core objective has and continues to be the representation of the dairy economy in ways that recognize its geographic, biological, marketing, and regulatory complexities.

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Others who have contributed in varying measures to the development of the U.S. Dairy Sector Simulator or to the analysis reported in this publication include Dr. David Jensen of Kingland Systems Corporation, Mr. Will Francis of the New York-New Jersey Milk Market Administrator's office, Dr. Maurice Doyon of Laval University, and Mr. Geoff Green of Cornell Universty.

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ABSTRACT

Economists have long considered issues of spatial economic activity, trade, and location values. Among all the various theories presented over the past century, it is safe to say that not one predicts that goods, services, or factors of production must attain the same value at different locations in geographic space. Only under the most extreme conditions, such as zero transportation costs, would it be even conceivable that the same commodity or factor of production be expected to command the same price in two geographically separated markets. With costly transportation, it is possible that two separate markets have nearly the same, or even identical, prices, but there are no theoretically justified reasons to expect such an outcome, *a priori*.

When the question is raised "why should the same hundred pounds of milk sell for as much as $3.00 more in some regions of the country than in the Upper Midwest?"[1] the answer is that 1) local supply, 2) local demand, and 3) transportation costs, as well as all those attendant conditions which determine these three factors simultaneously, interact to determine the location value of milk. Indeed, one would not expect that the same hundred pounds of milk have the same value everywhere. The important component of this question is 'how much different' these location values will be. Different prices for identical goods at separated locations is not difficult for the 'man/woman in the street' to acknowledge and should not be a mysterious concept to the dairy industry. Why is fresh seafood more expensive inland, why are grapefruit dearer in Ithaca, New York than Miami, Florida, why are apples higher priced in Miami; supply, demand, and transportation.

The U.S. Dairy Sector Simulator (USDSS) was constructed to provide insight into the optimal, efficient geographic flows of milk and dairy products; to provide guidance with respect to efficient plant location and size; and to evaluate the spatial value of milk and milk components across the U.S. Using 240 supply locations, 334 consumption locations, 622 dairy processing plant locations, 5 product groups, 2 milk components, and transportation and distribution costs between all locations, USDSS determines mathematically consistent location values for milk and milk components.

The results of our analysis demonstrate that, under conditions which prevailed in May and October of 1995, milk produced in the U.S. has distinct location values at geographically dispersed points of processing. A mathematically derived price surface for milk used in fluid uses indicates that these values have a range of $3.63 from the lowest valued location to the highest in May and $3.99 in October. Locally low levels are found in the Upper Midwest, the Northwest, and the West. Eau Claire, Wisconsin is not the lowest valued location in the U.S. nor do values increase uniformly away from Eau Claire or from any of the low valued locations. In fact, the spatial dispersion of values from low to high valued locations is much less than transportation costs alone would indicate. From the low valued locations there is an increasing value gradient generally to the east and, more markedly, to the southeast. Milk used in other dairy products also

[1] Congressman Steve Gunderson, "The Future for a National and Modern Dairy Industry," June 2, 1989.

has locationally distinct values which are much less pronounced than those for fluid milk uses. When compared to USDA's current system of location differentials for class I uses, and holding the total level of class I differential dollars constant, the calculated differential surface is generally flatter than the actual surface, despite the fact that the range from lowest to highest value for the calculated surface is slightly greater. Relative, revenue-adjusted values in the Upper Midwest, much of the Midwest, and in Florida are calculated to be higher than the current differential levels, while for much of the rest of the country, the calculated values are lower than current levels. Some of these federally-regulated areas with low calculated values, such as near Dallas, Texas, are estimated to have location values at or exceeding a dollar lower than the current relative differential. Other state regulated areas, such as Maine, Montana, and Virginia also have differences in excess of one dollar. As with fluid milk uses, the value of milk used in manufacturing varies with location, despite the conventional wisdom that the 'national' character of these product markets somehow means there should be only one national manufacturing milk value. The optimally determined manufacturing values vary much less than the fluid values.

INTRODUCTION

Some History of Dairy Market Modelling

Spatially formulated trading models were prominent among the first uses of the newly discovered linear programming methods developed by George Dantzig in 1947.[2] In fact, the first use of the simplex method was for a logistics problem involving troop deployment across space. Economists and agricultural economists alike embraced the new programming methods and quickly began to apply them to practical problems, many of which were spatially oriented. Paul Samuelson's famous 1952 paper in the *American Economic Review*[3] spawned the later works of T. Takayama and G. Judge in using non-linear programming methods for similar problems. More recently, Takayama himself acknowledges the place of linear programming in the tools of a spatial economist[4] and credits E. O. Heady with promoting the use of linear programming by 'energetically' applying linear programming methods to economic decision-making in agriculture.

The dairy industry was an especially fertile sector in which to use these newly developed solution techniques. Even prior to the modelling revolution brought about by Dantzig's simplex method, researchers were formulating spatial dairy problems for analytical examination. In 1941, Kasten Gailius wrote "The Price and Supply Interrelationships for New England Milk Markets", an M.S. thesis in Agricultural Economics at the University of Connecticut.[5] The very

[2]G. B. Dantzig, *Programming in a Linear Structure*. Comptroller USAF, Washington, D.C., 1948.

[3]P. A. Samuelson, "Spatial Price Equilibrium and Linear Programming," *Amer. Econ. Rev.* 42(1952):283–303.

[4]T. Takayama, "Thirty Years with Spatial and Intertemporal Economics," *Annals of Reg. Sci.* 28(1994):305–322.

[5]K. Gailius, *The Price and Supply Interrelationships for New England Milk Markets*, M.S. Thesis, University of Connecticut, 1941.

next year Hammerberg, Parker, and Bressler[6] used a hueristic procedure to derive an optimum dairy market organization for the state of Connecticut. Ten years later, Bredo and Rojko,[7] also studying the Northeast dairy sector, published an award winning study which laid-out the structure of a spatial programming problem which would be used in the later studies implementing the new solution algorithms.

The use of these new, powerful applied methods found a natural home in applied dairy marketing. Snodgrass[8] and Snodgrass and French[9] used linear programming to simulate efficient spatial organization of the U.S. dairy sector. Subsequent to these early works, many applications of programming methods to spatial issues in the dairy industry, using both linear and non-linear methods, followed. An apex in the use of programming methods for such spatial studies for the dairy industry was reached during the late 1970s and early 1980s when a large number of studies emerged. (For example, see Beck and Goodin, Boehm and Conner, Kloth and Blakley, McDowell, and Thomas and DeHaven, McClean, *et al.*, and Pratt, *et al.*)[10]

At the same time that the mathematical programming models of spatial organization and trade were rapidly developing, there were also new developments of more statistically oriented methods.[11] It is fair to characterize the statistical trade models as being much more oriented toward studies of international trade rather than toward regional or sub-regional analyses. Few statistical trade models at a smaller-than-country level have been done. This is mainly because of data limitations. Because statistical models must rely upon observations, it is necessary that

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[6]D. Hammerberg, L. Parker, and R.G. Bressler, "Supply and Price Interrelationships for Fluid Milk Markets" in "Efficiency of Milk Marketing in Connecticut," *Agric. Exp. Sta. Bull. 237*, University of Connecticut, Storrs, CT, 1942.

[7]W. Bredo and A. Rojko, "Prices and Milksheds of Northeastern Markets," *Bulletin No. 470*, Agric. Exp. Sta., University of Massachusetts, Amherst, MA, August 1952.

[8]M. Snodgrass, *Linear Programming Approach to Optimum Resource Use in Dairying*, Ph.D. Dissertation, Purdue University, West Lafayette, IN, 1956.

[9]M. Snodgrass and C. French, "Linear Programming Approach to the Study of Interregional Competition in Dairying," *S.B. 637*, Purdue University Agricultural Experiment Station, West Lafayette, IN, May 1958.

[10]R. L. Beck, and J. D. Goodin, "Optimum Number and Location of Manufacturing Milk Plants to Minimize Marketing Costs," *Sthn. J. Agr. Econ.* 12(1980):103–108.

W. T. Boehm and M. C. Conner, "Potential Efficiencies Through Coordination of Milk Assembly and Milk Manufacturing Plant Location in the Northeastern United States," *Res. Div. Bull. No. 122*, Virginia Polytechnic Institute and State University, Blacksburg, VA, 1976.

D. W. Kloth and L. V. Blakley, "Optimum Dairy Plant Location with Economies of Size and Market Share Restrictions," *Amer. J. Agr. Econ.* 53(1971):461–66.

F. H. McDowell, Jr., *Domestic Dairy Marketing Policy: An Interregional Trade Approach*, Ph.D. Thesis, University of Minnesota, December 1982.

W. A. Thomas and R. K. DeHaven, "Optimum Number, Size, and Location of Fluid Milk Processing Plants in South Carolina," *Agr. Exp. Sta. Bull. No. 603*, Clemson University, SC, 1977.

S. A. McLean, J. Kezis, J. Fitzpatrick, and H. Metzger, "Transshipment Model of the Maine Milk Industry," *Tech. Bull. No. 106*, University of Maine, ME, 1982.

J. E. Pratt, A. M. Novakovic, G. J. Elterich, D. E. Hahn, B. J. Smith, and G. K. Criner, "An Analysis of the Spatial Organization of the Northeast Dairy Industry," *Search: Agriculture*, Cornell University Agr. Exp. Sta. No. 32, Ithaca, NY, 1986.

[11]R. L. Thompson, "A Survey of Recent U.S. Developments in International Agricultural Trade Models," *Bibliographies and Literature of Agriculture No. 21*, ERS, USDA, 1981.

actual trade flows between the units being analyzed be observed and recorded. Commodity flows in international markets are routinely compiled because of concerns for compliance with government imposed economic and health regulations. Commodity flows within a specific country are much less likely to be complied (an exception would be a case like the provinces of Canada). Additionally, statistical trade models rely heavily on past observations for their prescriptive results. When the analysis involves no changes in regulatory or technological regimes, or when these changes are minor, the past may be a robust predictor of the future. In contrast, when there are significant regulatory or technological changes, or when the specific purpose of the analysis is to study the impacts of such changes, the heavy reliance on observations generated by a system which did not include these new regulations or technology makes it much more difficult to predict the impacts of such changes. "However, regression models, while they may be useful in estimating *ex post* commodity supply and factor demand relationships by regions, can hardly serve as useful tools for analysis of the important structural changes (especially when these revolve around technology)which cause change in competitive or equilibrium positions among regions and, thus, cause the useful questions of interregional competition to be posed".[12] Programming models require the modeller to explicitly or implicitly express the regulatory and technological parameters used in the analysis.

The Model

The U.S. Dairy Sector Simulator (USDSS)[13] is a spatially detailed model of the U.S. dairy industry. It is formulated as a capacitated transshipment model with three market levels: farm milk supply, dairy product processing, and dairy product consumption. While few trade models include more than two market levels, it would be difficult to argue that producers, on the whole, trade directly with consumers without the involvement of some type of intermediary. These intermediaries could be simply wholesalers and/or retailers, or they could provide substantial value added functions and services such as a dairy processing plant would do. In any case, recent research is focusing on the role of intermediaries in determining market outcomes in spatial trading contexts. For example, see Anania and McCalla;[14] Bishop, Pratt, and Novakovic;[15] and Roy.[16]

Five dairy product groups are distinguished at the processing and consumption levels in USDSS: fluid milk products, soft dairy products, hard cheeses, butter, and dry-condensed-

[12]E. O. Heady, "Aggregation and Related Problems in Models for Analysis of the Agricultural Sector" in *Interregional Competition Research Models*. (edited by R.A. King), The American Policy Institute, 1963, p. 142.

[13]J. Pratt, P. Bishop, E. Erba, A. Novakovic, and M. Stephenson. "A Description of the Methods and Data Employed in the U.S. Dairy Sector Simulator, Version 97.3," R.B. 97-09, Dept. of ARME, Cornell Univ., Ithaca, NY, July, 1997.

[14]G. Anania and A. McCalla, "Does Arbitraging Matter? Spatial Trade Models and Discriminatory Trade Policies", *AJAE*, 73(1991):103-17.

[15]P. Bishop, J. Pratt, and A. Novakovic, "Using a Joint-Input, Multi-Product Formulation to Improve Spatial Price Equilibrium Models", Staff Paper 94-06, Dept. of ARME, Cornell Univ., Ithaca, NY, May, 1994.

[16]J. Roy, "Trade With and Without Intermediaries: Some Alternative Model Formulations," *Annals of Regional Sci.* 28(1994):329-343.

evaporated dairy products. Because these various processed and consumed dairy products rarely use the components of milk in the same proportion as they are available in farm milk supplies, USDSS uses a multi-component characterization of milk and dairy products. Currently, fat and solids-not-fat are used to account for the supply and use of the valuable constituents in milk. Dairy product processing plants must 'balance' the use of milk components in the various dairy products by moving intermediate dairy products between uses, and often across space, i.e., by-products of one processing operation must be moved from that operation to another for use in a subsequent dairy process. For example, excess cream may move from a fluid plant to a butter plant. USDSS simultaneously analyzes the optimal location of processing facilities, farm milk assembly movements, interplant transfers of intermediate dairy products, and dairy product distribution movements. Given estimates of producer milk marketings, dairy product consumption, processing costs, and transportation costs for moving milk from farms to plants, intermediate dairy products between plants, and processed dairy products from plants to consumers, USDSS finds the least cost organization of milk, interplant, and distribution flows as well as efficient processing locations and sizes.

U.S. milk supply is represented by 240 specific geographic locations in USDSS. Each location represents the milk supply of a set of contiguous counties from among the 3,111 U.S. counties. Similarly, U.S. dairy product consumption for each of the five product groups noted above is represented by 334 specific geographic locations. Each supply location, therefore, represents, on average, 13 counties and each consumption location represents, on average, 9 counties. There are 622 potential processing locations for each type of dairy product processed. USDSS can be unconstrained with respect to processing locations, or it can be constrained to process only at specific geographic locations for any product type consistent with current dairy processing capabilities. The current base model for 1995, using constrained processing, has 790 potential dairy processing locations of all types. Substantial effort and resources were expended on maximizing the level of spatial disaggregation used in USDSS. For the milk supply and dairy product consumption nodes, U.S. counties were used as the initial unit of analysis. These were aggregated to multi-county units which, in turn, were represented by specific geographic points. For processing nodes, actual processing facilities were aggregated directly to specific geographic points. There are trade-offs between the level of disaggregation, the effort which must be expended to collect and update the base data, and the benefits derived from disaggregation. Somewhere a balance has to be struck. We have been guided in these decisions by the thoughts of Earl O. Heady on this topic.

> "The intensity of the aggregation problem is, partly, a function of the purposes of the investigation. If the only purpose of the model application and empirical attempt is illustrative and to show, in fact, that one can be in the 'style of the economist' by actually estimating some quantitative supply and demand relationships, deriving therefrom some equilibrium prices and quantities, concerns in aggregation can be minimized. Perhaps not a small portion of research in agricultural economics currently falls in this realm: to 'be in style' by assembling a few data and coefficients as an illustration that one has applied the latest empirical technique. When the analysis is for these style or illustrative purposes alone, basic aggregation considerations are secondary and perhaps unimportant. However, when the analysis is expected to

predict response relationships, production patterns or optima which will serve in outlook and guidance for policy, educational programs or farmer investment decisions, problems of aggregation take on a great deal of importance. It is no longer sufficient to draw an arbitrary boundary around a number of states for which data are readily available and term the contents a meaningful region."[17]

Dairy industry issues are intensely locational. In our judgment, maximum, feasible spatial disaggregation is necessary to provide useful 'guidance for policy' with respect to issues which are intensely locational themselves.

What The Model Isn't

Samuelson's 1952 paper[18] paved the way for substantial progress in the area of applied spatial price equilibrium analysis. His paper gave rise to an entire body of analysis which continues to grow and evolve. Much of the effort, subsequent to the initial rash of analyses, has been to develop new solution algorithms which can solve much larger, more complicated problems and allow for much more general mathematical specifications for the demand and supply relationships. Takayama and Judge's path-breaking work was initially confined to linear supply and demand relationships, so quite naturally much of the earlier work was oriented toward expanded solution capabilities.

One of the earliest competitors to the quadratic-programming methods proposed by Takayama and Judge was 'reactive programming' proposed by Tramel and Seale,[19] Unfortunately, the convergence properties of this heuristic procedure were never fully explored and, despite its appeal from the standpoint of simplicity and usability, it never attained much popularity. More popular extensions were pursued along the lines of general non-linear programming methods,[20, 21] whereby the geometry of Samuelson's article is followed closely and transparently. Even more recently, further computational advances have allowed spatial modelers the flexibility

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[17]E.O. Heady, *op. cit.*, p. 129.

[18]P.A. Samuelson, *op. cit.*

[19]J. E. Tramel and A. D. Seale Jr, "Reactive Programming—Recent Developments," Chaps. 4 and 5 in *Interregional Competition Research Methods, op. cit.*

[20]F. Holland and J. Pratt, "MESS: A Fortran Program for Numerical Solution of Single Commodity Multi-Market Equilibrium Problems with Nonlinear Supply and Demand Functions and Flow Distortions," *Sta. Bul. 296*, Purdue Univ., West Lafayette, IN, Nov. 1980.

[21]T. Takayama and T. MacAulay, "Recent Developments in Spatial (Temporal) Equilibrium Models: Non-linearity and Existence and Other Issues", *International Commodity Market Modelling: Advances in Methodology and Applications*, O. Gouvenen, W. Labys, and J.B. Lesourd (eds.), 1991.

to capture the structure of even more complicated questions of spatial competition. For example, fixed points,[22] mixed complementarity problems,[23] and variational inequality problems.[24]

In contrast to the textbook type of problems where supply and demand curves cross to determine the equilibrium quantity traded at an equilibrium price, fixed production and consumption models of interregional trade presume that the quantities of commodity supplied and demanded are invariant over the length of analysis and that the commodity price adjusts to meet the equilibrium conditions. Fixed production and consumption models have a long and illustrious history in agricultural economics.[25, 26] Simple models of this structure can provide many insights for a broad class of regional trading problems. Those who might argue that once regional supplies and demands are specified, nothing else of interest need be determined, neglect the facts that 1) inter-regional prices still bear the burden of adjustment and 2) much of the 'marketing' of milk and dairy products occurs between the farm and the consumer. Issues such as what and where to processes specific dairy products, from where to assemble the ingredients, be they milk received from farms or inter-plant flows of intermediate products, and where the final products will be sent are indeed part of the solution and may be as important as the level of milk supply and product consumption. There are many, many market variables to be determined, despite given supply and consumption quantities.

There have been similar mathematical models of the dairy industry constructed to analyze very specific Federal Milk Marketing Order questions. An early model built by Babb, FMMOPS,[27] considered the then forty-five Milk Marketing Orders as spatial centers with consumption, processing capabilities, and, potentially, two sources of milk, direct shipped and supply plant milk. Transportation and processing costs as well as processing capacities and restrictions on shipments, such as minimum shipping requirements for pool qualification, were also considered. Milk was assigned to three classes, each of which had a unique, order determined, class price. Based on these class prices and uses, blend prices for each order were computed. Direct ship milk was assigned to orders on the basis of net blend prices (i.e., the difference between the blend price in the pooling order and the transportation cost of going to a plant in that order) and supply plant milk moved from order to order based on the net, transportation

[22]J. MacKinnon, "A Technique for the Solution of Spatial Equilibrium Models", *J. of Reg. Sci.* Vol. 16, no. 3, 1976.

[23]T. Rutherford, "Applied General Equilibrium Modeling Using MPS/GE as a GAMS Subsystem," Discussion Paper 92-15, Dept. of Econ, Univ. of CO, Boulder, Aug. 1993.

[24]A. Nagurney, C. Nicholson, and P. Bishop, "Spatial Price Equilibrium Models with Discriminatory *Ad Valorem* Tariffs: Formulation and Comparative Computation Using Variational Inequalities," Chap. 9 in *Recent Advances in Spatial Equilibrium Modelling: Methodology and Applications*, J. C. J. M. van der Bergh, P. Nijkemp, and P. Rietveld (eds.), 1996.

[25]R. A. King, "Fixed Production - Fixed Consumption Models with Processing Introduced," *Interregional Competition Research Methods, op. cit.*

[26]J. F. Stollsteimer, "Fixed Production - Fixed Consumption Models with Processing Introduced," *Interregional Competition Research Methods, op. cit.*

[27]E. M. Babb *et al.*, "Economic Model of Federal Milk Marketing Order Policy Simulator-Model A," *Sta. Bul. 158*, Purdue Univ., West Lafayette, IN, 1977.

cost adjusted, difference in class I prices. The model could be solved for up to twenty quarters, between which the quantities of milk produced and consumed in each order were adjusted according to their estimated elasticities to reflect the prices from the previous period. Similarly, new, optimal flows of milk between orders was computed on the basis of local price differences and transportation costs. Based on the class prices and computed blend prices in each order, new consumption and supply levels were determined for the next quarter.

Novakovic[28] expanded and extended the detail of FMMOPS to include state regulated markets as well as unregulated grade A and B milk. The Dairy Market Policy Simulator, DaMPS, includes manufactured product imports and both government and commercial storage activities. These market aspects became important components in an era when Commodity Credit Corporation (CCC) purchase activities were historically high and when the support price was an important determinant of market outcomes.

USDSS contains none of the regulatory detail present in FMMOPS or DaMPS. USDSS expends its mathematical degrees of freedom, so to speak, on spatial disaggregation as noted above. More complex institutional constraints or incentives are modelled as side analyses or formulated within the existing mathematical framework.

SHADOW PRICES AS PRICES

The proliferation of complex spatial trading models or inter-industry models with spatial contexts has been quite remarkable. When considered in it's simplest form as an exercise in finding the intersection of a supply and demand response function, or of a set of such functions, it's of little surprise that these models have great appeal to economists. However, it is somewhat surprising that those same interests have all but forgotten that spatial trading models have their roots in linear programming, given that Samuelson's pathbreaking article made this connection explicitly clear, as its title indicates. These 'fixed production and consumption' models, where quantities both desired and available are considered pre-determined, provided Samuelson with his 'inside' problem—a transportation formulation—whose dual information along with which transportation costs could be used, in turn, to compute equilibrium market prices in the more familiar situation of price responsive supply and demand.

This transportation problem, where we have only two market levels, was formalized by Tjalling Koopmans in the 1940s and 1950s (partly for which he received an Noble prize in economics in 1975), and was one of the first problem types to be rigorously attacked with the new linear programming algorithms. In this problem, we have:

m = the number of supply sources
n = the number of demand sinks
a_i = the supply at source i

[28] A. M. Novakovic et al, "An Economic and Mathematic Description of the Dairy Market Policy Simulator (MODEL A)," *A.E. Res. 80-21*, Cornell Univ, Ithaca, NY, 1980.

b_j = the demand at sink j
$c_{i,j}$ = the per unit cost of transporting the commodity from source i to sink j
and
$x_{i,j}$ = the quantity shipped from i to j.

There are three basic conditions for the quantities shipped which must be met in order for any particular problem of this type to have a feasible solution:

$$x_{i,j} \geq 0 \text{ for } i=1,...,m \text{ and } j=1,...,n \tag{1}$$

We have nonnegative quantities shipped. This literally means that we cannot run things backwards, creating supply out of demand. This is not to be confused with having other types of points, such as intermediaries, which can both receive and send shipments; a transshipment problem. USDSS is such a formulation whereby dairy processing plants both receive raw materials and ship final or intermediate products.

$$\sum_{j=1}^{n} x_{i,j} \leq a_i \quad \forall i=1,\ldots,m \tag{2}$$

Total shipments from any supply source i must not exceed the quantity available at that source.

$$\sum_{i=1}^{m} x_{i,j} \geq b_j \quad \forall j=1,\ldots,n \tag{3}$$

Total shipments to any demand sink j must meet or exceed the quantity required at that sink.

We wish to find a feasible solution to (1), (2), and (3) in $x_{i,j}$ which minimizes the total transportation cost:

$$\text{Minimize} \sum_{i=1}^{m} \sum_{j=1}^{n} c_{i,j}\, x_{i,j} \tag{4}$$

A necessary condition for the solution of this problem is that total demand must be less than or equal to total supply. By summing (2) over m and (3) over n, we can derive the following relationship;

$$\sum_{j=1}^{n} b_j \leq \sum_{i=1}^{m} \sum_{j=1}^{n} x_{i,j} \leq \sum_{i=1}^{m} a_i \tag{5}$$

This necessary condition states the obvious, that total demand can be no larger than total supply.

This problem can be restated in the normal mathematical programming format as:

$$\text{Minimize} \sum_{i=1}^{m} \sum_{j=1}^{n} c_{i,j}\, x_{i,j} \tag{6}$$

$$\text{Subject to} \sum_{j=1}^{n} x_{i,j} \leq a_i \tag{7}$$

$$\sum_{i=1}^{m} x_{i,j} \geq b_j$$

$$x_{i,j} \geq 0, \text{ for } i=1,\ldots,m \text{ and } j=1,\ldots,n \tag{8}$$

This is the 'primal' form of the transportation problem, whereby the optimal, yet initially unknown, shipments, $x_{i,j}$, can be selected in such a way so as to minimize transport cost, while 1) satisfying demands, 2) respecting supply limitations, and 3) not allowing the creation of supplies out of demands, the nonnegativity conditions on $x_{i,j}$ This very simple primal problem structure fits a number of surprisingly dissimilar applied optimization problems and has proven itself very useful for problems of spatial organization, where the optimal shipments between supply points and consumption points are determined so as to meet the constraints while minimizing total transportation costs. Modern computers with state-of-the-art software are capable of reasonably solving problems of this type with millions of variables, $x_{i,j}$, and tens of thousands of constraints.

Accompanying every allocation problem, the primal noted above, is a mathematically defined equivalent 'dual' problem which provides the concomitant optimal valuation of limited resources ('dual' or 'shadow' values) embodied in the constraints. The optimal objective values for the primal and its associated dual problem are identical, i.e., the sum of the dual values times their respective resource levels gives the same value as the minimized total cost from the primal. There is an optimal dual value associated with each resource constraint in a mathematical programming formulation. These optimal dual values are an integral and useful part of any mathematical programming solution. Literally, dual values are the change in the objective function resulting from a one unit (actually calculated as a derivative) change in a resource availability. These 'imputed' values give important information about the optimal resource valuations which can be interpreted in a managerial context. They predict the change in the optimal objective value associated with a change in the availability of a resource. Resources which are in excess, which are not totally exhausted by activities associated with the optimal solution, will have zero imputed values. At the margin, adding or removing another unit of a resource which is already underutilized will add nothing to one's ability to improve the given objective. Adding or removing another unit of a resource which is fully utilized will change one's ability to optimize the objective. These types of derived relationships for dual values result from the 'complementary slackness' conditions, a set of mathematically determined primal/dual conditions which must hold for any optimal solution to a mathematical programming problem. The dual values are 'imputed' (meaning 'the value of a resource being determined from its utility rather than by adding the cost of its constituent elements'), i.e., these values are determined entirely with the context of the mathematical program at hand. *No other information or opportunities, other than those contained in the program, are involved in determining these imputed values.*

Duality holds a special place in the world of spatial economics. Generally in mathematical programming, dual, sometimes called 'shadow' or 'imputed', values which are associated with optimization of some objective over a set of given resources can be interpreted as the concomitant optimal resource valuations. In a transportation context, these 'resources' are 1) supplies of the commodity available to be shipped from the various supply sources, 2) demands for the commodity required to be shipped to the various consuming locations, or 3) capacity limitations on processing. In USDSS, we do not use capacity limits at processing locations, so there are dual values associated with quantities supplied, consumed, and processed. The resource units in a transshipment problem like USDSS are the actual quantities of a commodity (milk in this case). The objective is stated in terms of dollars per unit of the commodity and the dual values are also denominated in this unit. A unit change in a resource, in this case, is literally a unit change in supply, consumption, or processing. The dual value associated with such a change is then denominated in dollars per unit of supply or consumption, an imputed 'price'.[29] In the transshipment context, the set of imputed values for the supplies and demands associated with specific locations defines the set of equilibrium prices for those locations. This dual problem, or 'inside' problem to which Samuelson referred, provides us with some familiar rules governing price behavior in this simple fixed production—fixed consumption model (in the absence of trade flow distorting mechanisms); 1) any location at which supplies are not totally exhausted will have a local imputed price of zero, 2) the imputed price difference between two points in geographic space cannot exceed the transportation cost between these two places, 3) the imputed price difference between two points in geographic space which actually do trade with each other must equal the cost of transportation between these points, and 4) two places whose local price difference is not as great as transportation costs will not trade.

By way of complementary slackness, any supply location which is characterized by underutilized commodity, in the optimal solution, will have an imputed price of zero. What sense does such a price make? Given that the dual prices are imputed from the programming model, they only embody the information present in the model. In the transportation formulation above, if the $c_{i,j}$'s, the costs of moving a unit of commodity from location i to location j, does not include the cost of producing or extracting that commodity to make it available at location i in the first place, then the imputed prices will not include the initial production or extraction costs. Even if such costs were included in the $c_{i,j}$'s, in cases where the total supply in the model is greater than total consumption, at least one supply source would have a zero imputed value. The marginal unit of supply at that source can have no impact on the objective function. While such underutilized supply might have an actual reservation or salvage price, unless this value were

[29] G. L. Thompson and S. Thore, *Computational Economics*, Chap. 13, 1992.

explicitly included in the programming formulation, say as the price on an excess demand point (a point to which all underutilized supplies flow), unused supplies would be valued at zero. These imputed value interpretations give useful 'managerial' information which would give guidance to decisions with respect to logistical management and control.

If two potential trading locations have an imputed price difference, then at least one of those locations must have a positive imputed price. If the transportation cost between these two locations is less than the imputed price difference, moving a unit of commodity from the low priced location to the higher priced location would result in a net gain in value for that unit, or, equivalently, a reduction in total costs. At optimality, total costs are minimized so the imputed value differences between potential trading locations would not be greater than their associated transportation costs.

If, in the optimal solution, two locations, i and j, trade, their imputed values will be directly linked by this primal trade flow so that their value differences will equal transportation costs. For this trade flow from i to j, if the imputed value difference between i and j was less than transportation costs, shipping from i to j would result in lost total value. Transportation cost would outweigh the gain in location value represented by the location value difference. For this trade flow from i to j, if the imputed value difference between i and j was more than transportation costs, shipping from i to j would result in gained total value. Transportation cost would be outweighed by the gain in location value. This would create an incentive to shop more commodity from i to j, increasing total commodity value. Thus, the initial flows are clearly not an optimal solution. Opportunities to gain total value would not occur at optimality and the imputed values would have to be adjusted until the difference in imputed values between trading locations exactly equaled transportation costs. Two potential trading locations whose value differences are less than their associated transportation costs at optimality will not trade. Two potential trading locations who do trade in the optimal solution, must have imputed value differences which are equal to transportation costs.

The imputed values from transportation/transshipment problems can be interpreted as market prices. They are expressed in the correct units and they are associated with quantities supplied and consumed. They may not, however, include all of the elements which make-up an actual 'observed' price; those production or extraction costs noted earlier. When these price elements are included in the primal problem, the imputed value differences represent the location and transportation cost determined differences in spatial prices rather than the spatial market prices themselves. Issues involving raw materials costs and/or marketing margins may best be approached as 'side analyses' (see Bressler and King, p.98) where the basic transportation problem solution is augmented with additional market information. Additionally, it must be stressed that the simulated shadow values presented below have concomitant primal solutions. Each value surface has associated with it a set of milk and product flows which are derived by minimizing dairy industry cost across the entire U.S. for all dairy products.

ESTIMATED SHADOW VALUES AND DERIVED CLASS I PRICE DIFFERENTIALS

Federal milk marketing orders have typically used spatially differentiated prices to encourage economic efficiency and orderly marketing in regulated markets where minimum trading prices between producers and processors are imposed. Class I prices typically vary both across and within orders. Table 1, column 1, lists class I differential values at 240 geographic locations across the U.S. The listed locations represent a subset of the cities from which USDSS may choose to locate processing facilities in the optimal industry configuration. Most of these differentials are computed for the applicable Federal order, but some are based on local state order regulations (see the F (Federal) or S (State) indicator after the city name in Table 1). Miami and Deerfield Beach, Florida, federally-regulated points, have the highest actual differential level at $4.18. Charlottesville, Lynchburg, Norfolk, Richmond, and Roanoke, Virginia, state-regulated points, are not far below at $4.03. Wausau, Wisconsin, at $1.04, is the lowest differential. The weighted average actual class I differential for the 48 contiguous states (weighted by the class I sales estimates used in USDSS) in May, 1995 was $2.49. High and low values give one measure of the shape of the differential surface and a weighted standard deviation gives another. The standard deviation for these actual differentials, $0.76, indicates that a high proportion of the fluid milk which is processed at these actual differentials (71%) has an applicable differential within $0.76 of the weighted average. Figure 1 depicts a contour map of the actual Federal and state regulated class I differentials at the 240 geographic locations reported in Table 1.

As one can see, actual differentials do generally increase in a more or less 'regular' fashion with distance to the east and south of the Upper Midwest. To the west, however, there is little or no regularity of differentials *vis-á-vis* the Upper Midwest.

Figure 2, using the same relative coloration as Figure 1, depicts an 'Eau Claire plus transportation costs' surface. This arrangement is often purported to be the rule by which class I location values are determined. Table 1 lists the transportation cost-determined differentials. Figures 1 and 2 and columns 1 and 2 of Table 1 each have Minneapolis, Minnesota valued at $1.20. It can be seen that the general shape of the actual differential surface resembles the 'Eau Claire plus' surface from the Midwest to the east coast, with increasing values arrayed in somewhat concentric rings with Eau Claire as the foci. However, the actual differentials are everywhere much lower than actual transportation costs would indicate. To the west, there is no resemblance between the 'Eau Claire plus' and actual values. Actual differentials are everywhere less than any value determined by transportation cost alone would suggest. In a purely transportation cost determined system with Minneapolis, Minnesota at $1.20, Eau Claire, WI would be valued at $0.88, and Salinas, California, being the farthest from Eau Claire, is the highest valued point, at $9.37. The weighted average transportation determined differential of $5.22 and the standard deviation of $2.12 indicates that transportation cost determined differentials would be much higher than the current levels.

Producer blend prices within an order, though starting from a uniform base, have typically varied across space in the same manner as that order's class I price. One must keep in mind, however, that a regulated market has two distinct types of prices; class prices which are those minimum prices regulated processors are required to pay and blend prices which are those

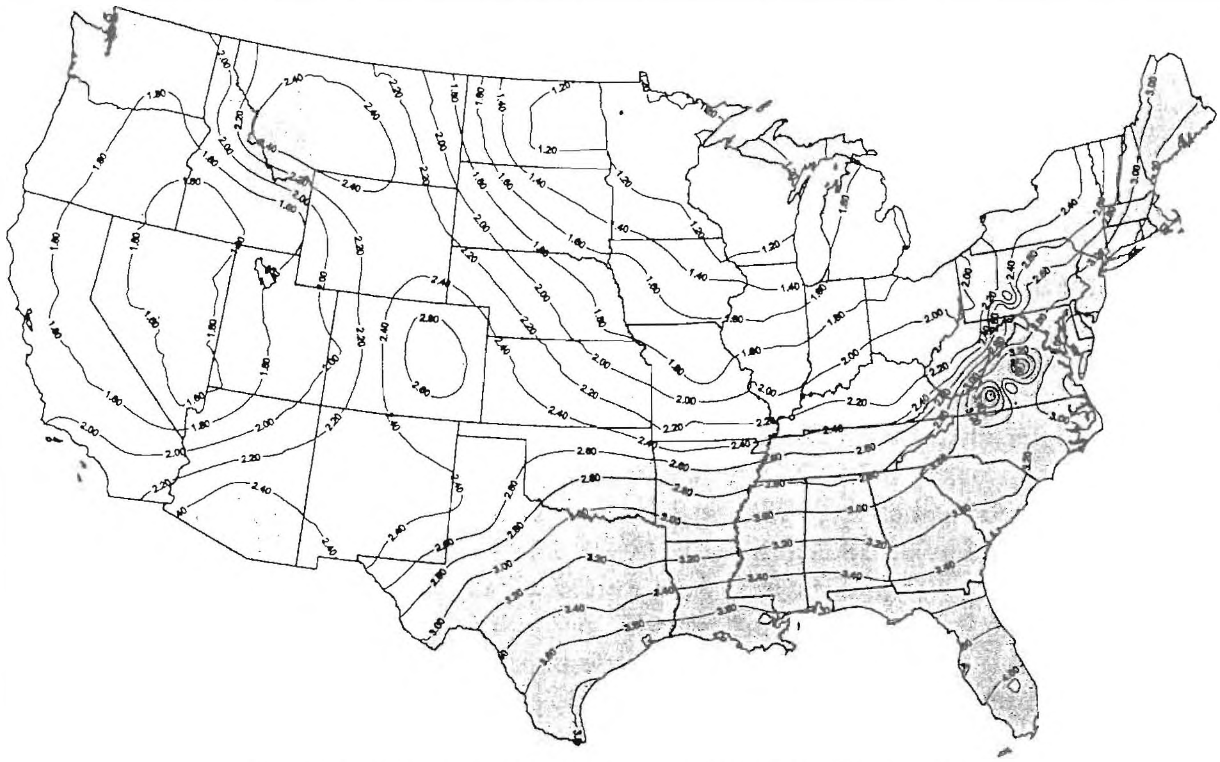

Figure 1. Actual Federal and State Class I Differentials:
Based on 240 Selected Locations

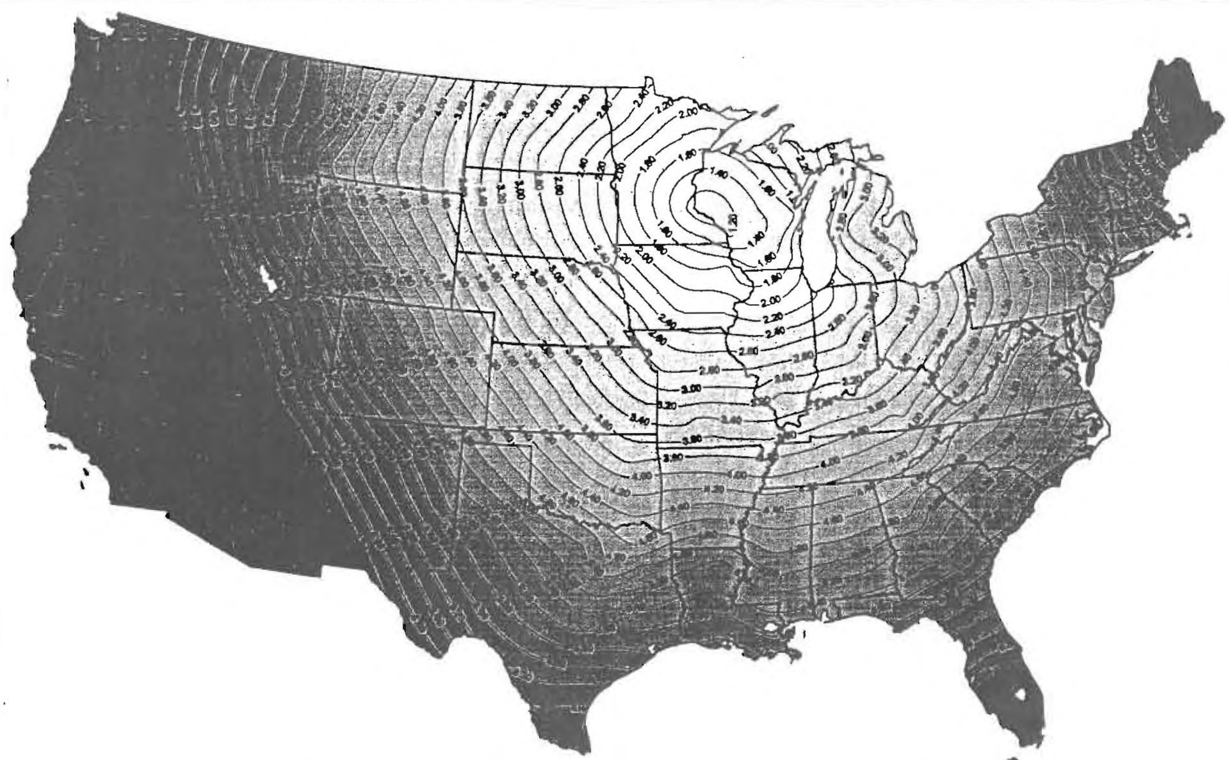

Figure 2. Eau Claire, WI Plus Transportation Cost
(Minneapolis, MN = $1.20)

minimum prices which producers shipping to regulated processors will receive. The marketwide pooling and blending of the receipts from processors before these receipts are disbursed to producers is a fundamental tool in establishing equitable prices to producers.

A number of complicating factors characteristic of dairy markets, e.g., the multiple component-joint product nature of milk, the relatively high cost of transportation, the limited opportunities for storability, and the counter-seasonality of production and consumption, make the establishment of efficient, orderly, market prices a difficult task (see R. G. Bressler, "Pricing Raw Product in Complex Milk Markets," *Ag. Econ. Res.*, 10 (October 1958):113-130). The USDSS is used to capture the impacts of several of these complicating factors in estimating the spatial value of milk and milk components at specific geographic locations in the U.S. The impact of seasonality, while not directly estimated in a single model, is investigated by considering base data for two months; May and October, 1995. While there are 622 potential cities at which USDSS can locate milk processing plants, in this base situation, the number of locations is restricted to cities which are chosen to represent significant, actual processing locations. There are 319 cities from which the USDSS can pick to process fluid milk products, 147 for soft, 178 for cheese, 71 for butter, and 60 for powder, condensed, and evaporated products. In the optimal base solution, USDSS chose to use 236 fluid, 98 soft, 86 cheese, 14 butter, and 58 powder, condensed, and evaporated locations. In the base situation, there were no restrictions placed on the quantity of milk or product which could be received or processed at any of these locations, i.e., no processing capacity limitations were employed in the base situation.

Shadow Values at Fluid Plants in the Base Solution

All results presented below use the May, 1995 base data unless specifically noted otherwise. A separate section is included to compare and contrast the results for May and October.

The shadow values from USDSS associated with processing locations, using May 1995 dairy marketing data, describe a set of relative prices which are consistent with an efficiently organization U.S. dairy industry. The optimal solution allocates milk to processing facilities for the different classes of products, while minimizing the combined aggregate cost of milk assembly and product distribution. The result represents an 'ideal' short-run (monthly) solution.

Corresponding to each optimal fluid processing location determined by USDSS for the base month, a relative shadow value for milk at that particular geographic point can be determined. This value, literally interpreted, indicates the change in the optimal objective value resulting from a one unit change in the availability of standarized milk (3.5% butterfat (fat) and 8.62% solids-not-fat (snf)) at the particular fluid processor in question; the optimal valuation of milk delivered to the fluid processor. Because USDSS is formulated on a milk component basis, component values at plant locations can be converted directly to standardized milk equivalents. As noted above, only value *differences* between geographic locations can be generated using the results of USDSS and these differences reflect only the 'transportation' derived component of class I price location differentials. As such, there would be some geographic points where the derived differentials, made-up of transportation value only, would be very low relative to the actual market levels which include other differential components, most notably the primary cost of milk production. These shadow values could be reported directly, indicating the transportation related component of spatially differentiated class I values. However, it is our experience that such values, lacking any fixed-value component, while being conceptually simple, are deceivingly difficult to put into interpretive context, even for persons very familiar with current dairy markets. Several different procedures could be utilized to convert these price relatives into values which have more absolute level relevance.

The relative shadow values could be 'pegged' to a value at some specific location. We have done this many times in the past, using $1.20 at Minneapolis, Minnesota, a low-valued point in the current system. An identical constant was added to every shadow value obtained in the base USDSS solution, such that the computed value at Minneapolis, Minnesota became $1.20. *The constant which was used to derive a specific location's value would then be added to every class i processing shadow price from USDSS.* In this manner, the reported values approach values which have levels in the range of actual differentials, while the price relatives from USDSS are maintained. Of course, a high valued location such as Miami or Boston could have been picked as well, or, for that matter, any one of the 622 potential processing locations could serve as the base to which all other locations are pegged. The advantage of this procedure is that it generates local values which 'look' similar to current levels. A disadvantage is that the number generated for Minneapolis, Boston, or Miami, will never change. It is fixed at the applicable 'base' value. Other locations will be higher or lower relative to the city chosen and relative to their current levels, but it gives the impression that some certain area of the country is being exempted from change.

A second approach, as an alternative to the arbitrary designation of a specific geographic point as the base, is to calculate a constant value such that when this constant is added to all class I shadow values, total system-wide class I pool dollars are equal to current levels. In this option, an estimate of total national class I differential dollars is made, i.e., dollars added to total system pool values by minimum prices in excess of the basic manufacturing price. A constant, similar to the one used above in 'pegging' a specific location, is calculated so that the total, optimally determined, national class I differential value is equal to the current value. *This constant would then be added to every class i processing shadow price from USDSS.*

A third approach is to simply add a constant which is neither 'pegged' to any location nor determined by trying to replicate some existing condition. The constant might be interpreted as some type of nontransportation related class I value. As of this writing, USDA has suggested the possibility of $1.60. As in the above cases, *This constant would also be added to every class i processing shadow price from USDSS.* In this case, such a constant could possibly represent the estimated cost of production or some similar concept.

It should be noted here that all of the above alternatives result in a single constant being added to every shadow price at class I processing locations utilized in the optimal base USDSS solution. The optimal relative price differences obtained by USDSS across space are maintained under each option. For purposes of presentation, the results presented below use the second alternative, whereby a constant value of $1.15 is added to the shadow price for 3.5% fat and

8.62% snf milk at each fluid processor location in the base USDSS solution. This adjustment results in a total national class I value which is approximately equal to the estimated actual value in May, 1995.

Figure 3 and Table 1, column 3, report these 'revenue-adjusted' class I spatial values. Like the 1995 actual Federal Order class I differentials depicted in Figure 1, the estimated national class I value surface is not flat, nor does it approach the steepness of the Eau Claire plus transportation cost determined values seen in Figure 2. While Thief River Falls, Minnesota, has the lowest value of $1.45, values are generally low in the Upper Midwest and Northwest and increase, though by no means uniformly, toward the South and East. The lowest valued areas (below $1.80) are located in northern Minnesota, eastern South Dakota, the Central Valley of California, much of Washington, and southeastern Idaho. Other relatively low valued local localities include areas near Phoenix, Arizona, Portales, New Mexico, Springfield, Missouri, Louisville, Kentucky, and Jamestown to Syracuse, New York. Miami, Florida, at $5.08 is the highest valued point and South Florida is by far the highest valued area. Other locally high valued areas include the area south of San Francisco, California, Las Vegas, Nevada, Sante Fe, New Mexico, Peoria to Chicago, Illinois, and the Boston, Massachusetts to New York City metroplex.

The weighted average revenue-adjusted differential of $2.47 indicates that the total class I generated value is nearly equal to the weighted average actual differential. The standard devia-

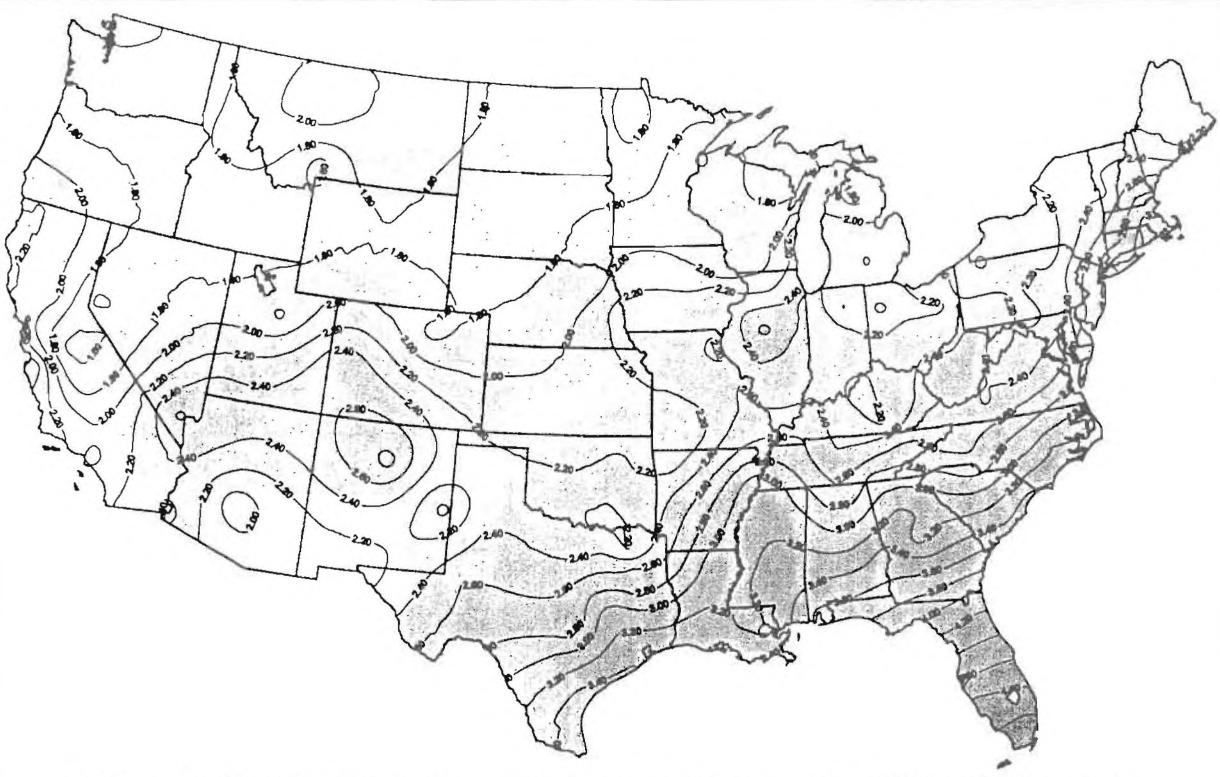

Figure 3. USDSS Model-Generated Revenue-Adjusted Class I Price Differentials ($/cwt @ 3.5% fat and 8.62% snf), May 1995

tion of $0.63 indicates that the simulated price surface is, by a statistical measure, less varied or 'flatter' than the actual surface, even though the range of low to high values is larger.

Table 1, column 5, and Figure 4 show the differences between the USDSS simulated revenue-adjusted differentials and the actual differentials at each fluid processing location chosen by USDSS for May, 1995. Chicago, Illinois has the largest positive difference, indicating that the actual differential in Chicago should be raised by $1.06. Charlottesville and Roanoke, Virginia have the two largest negative differences, $1.72 and $1.65, indicating that these two state regulated points should be lowered by these amounts. Points in Montana, Maine, and Pennsylvania, all state-regulated areas, have large negatives. Among Federally regulated areas, Austin and Dallas, Texas and Denver, Colorado show relatively large, suggested negative adjustments of $0.79, $0.69, and $0.82, respectively. On Figure 4, the green shading indicates areas where USDSS suggests increased differential values and the red shading indicates areas of decreased differentials. Darker colors indicate larger suggested changes; larger decreases relative to actual differentials for the dark red and larger increases for the dark green. Again, while simulated differentials suggest a widening in the range, they also suggest a flattening of the overall levels.

Figure 5 and Table 1, column 4, indicate that for the October, 1995 simulation, Miami, Florida and Thief River Falls, Minnesota are again the highest and lowest valued points with $5.36 and $1.37, respectively. The color-coded value surface, which has the same color gradation

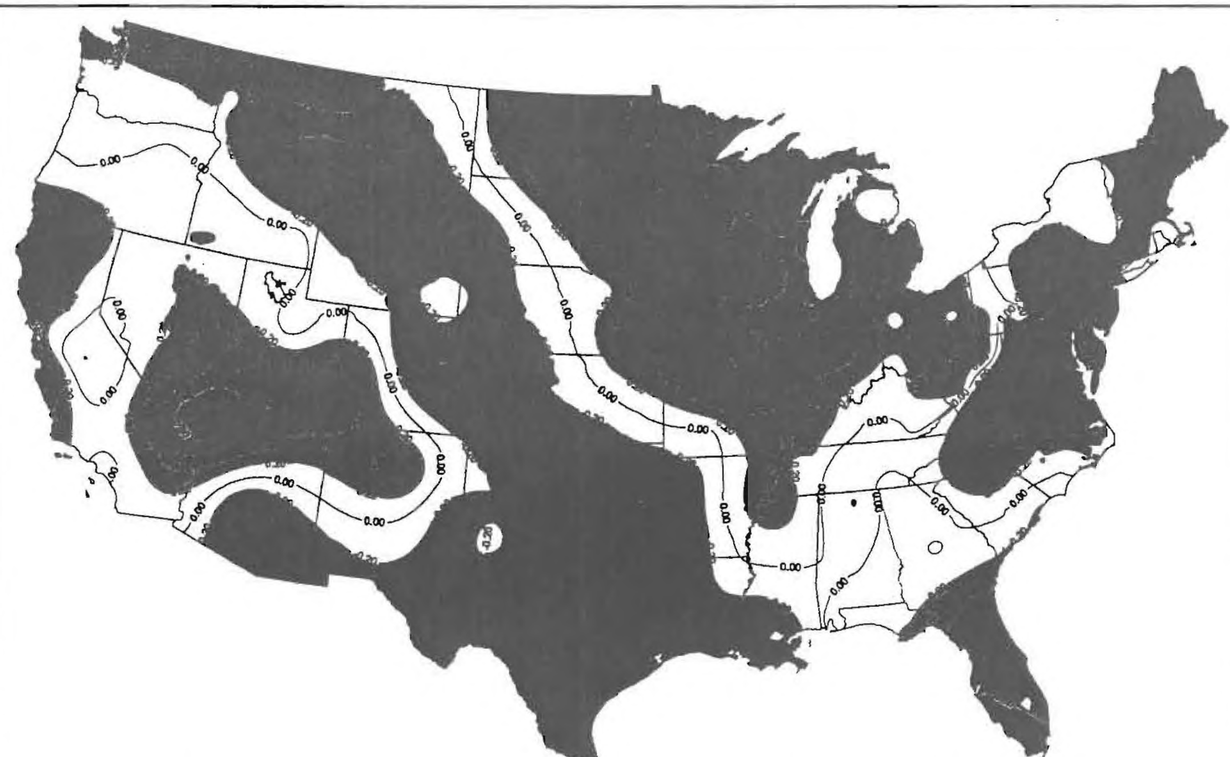

Figure 4. Differences Between Revenue-Adjusted and Actual Class I Differentials ($/cwt), May 1995 (red = -'s, green = +'s, and white = less than $0.20)

as previous figures, indicates that the October value surface is shaped much like the May surface with generally higher values in the Southeast and the East. By construction, the weighted average differential of $2.47 for October is calculated to be identical to the weighted average for May. The total class I differential dollars in the October pool is held constant to the same total amount of class I differential dollars in the May pool. It is conceivable that for the short month of October, the total differential dollars would have to be greater than for the long month of May. In order to attract enough milk for October's class I needs. In this situation, the $2.47 constant for October is too low and all values reported for the October, 1995 column in Table 1 would need to be increased. The weighted standard deviation of $0.72 for the October, 1995 simulated differentials indicates that the simulated October differentials are more varied than those for May and that the price surface is nearly as statistically 'unflat' as the actual differentials. Given that frequent changes in differential values are unlikely, it's a debatable issue as to what is the appropriate level. May levels are consistent with optimal organization in May, but may be insufficient to give incentive for high valued areas to attract milk in other, short months such as November. Similarly, November levels would be consistent with optimal organization in November, but may give incentives for non-optimal behavior in May. Intermediate months would have similar problems. A long month's values could be chosen and other order provisions such as transportation credits be used in short situations. Or market forces could be relied-upon to give the proper incentives for milk movements in short months. In the latter case, increased levels of market value are moved outside of the pool. Or, an average month's values could be chosen and non-

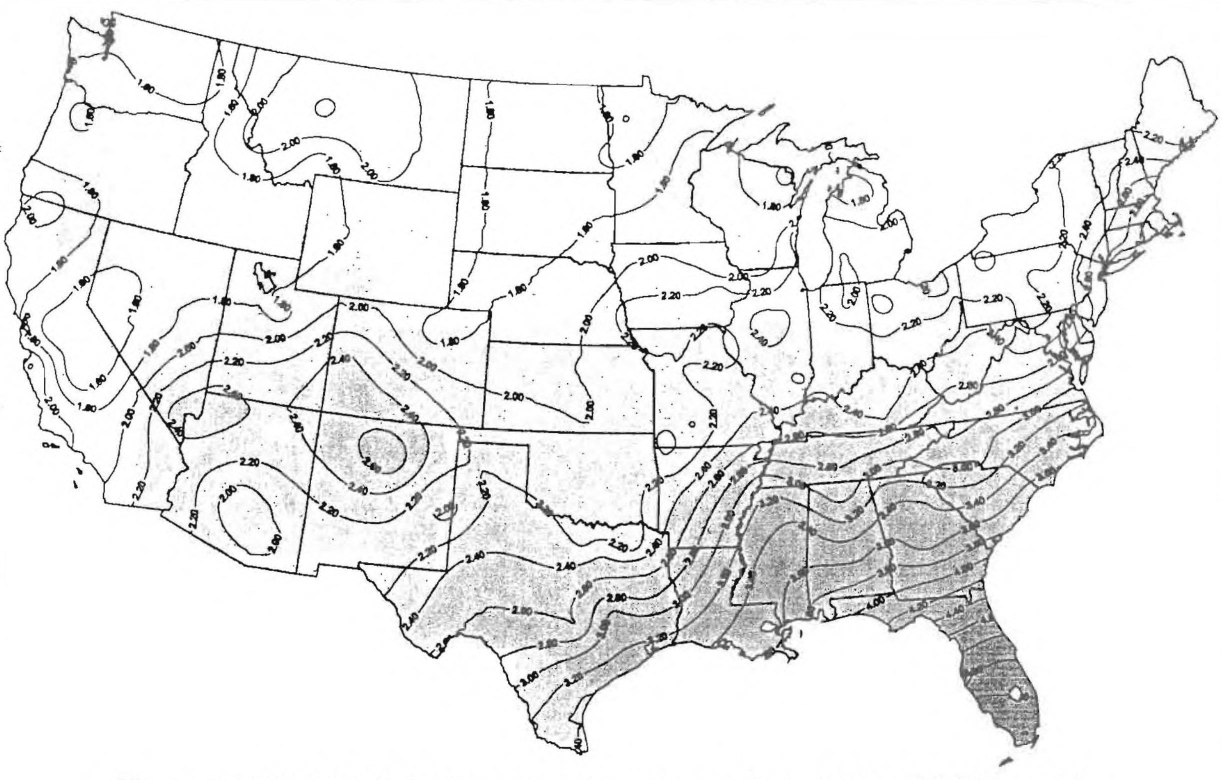

Figure 5. USDSS Model-Generated Revenue-Adjusted Class I Differentials ($/cwt @ 3.5% fat and 8.62% snf), October 1995

price tools such as shipping requirements or call provisions be used to encourage orderly and efficient outcomes.

Shadow Values at Manufacturing Plants in the Base Solution

Just as USDSS generates relative milk values at fluid processing locations utilized in the optimal solution, it also generates relative milk values at manufacturing locations. Figures 6-8 and Table 2, columns 1-3, indicate the relative manufacturing values for the May, 1995 base solution. As with fluid processing, the base solution restricts manufacturing operations to locations which were thought to have processed manufacturing products in 1995. USDSS is free to choose or not to choose to process at these locations, but is not free to select other locations. There are no restrictions on the quantities processed at any chosen location.

Figure 6 and Table 2, column 1, show that the location value of milk used to produce soft products differs by more than $1.40 from low to high. Generally, these values increase from low valued areas in the Northwest to high-valued areas in the East and Southeast. Figure 7 and Table 2, column 3, show that the location value of milk used to produce cheese differs by 71 cents from high to low. Numerical values posted on Figures 7 and 8 indicate plant locations as well as the value at the location. Again, the Pacific Northwest has the lowest values and these values increase gradually and somewhat uniformly to the east, where the highest values are

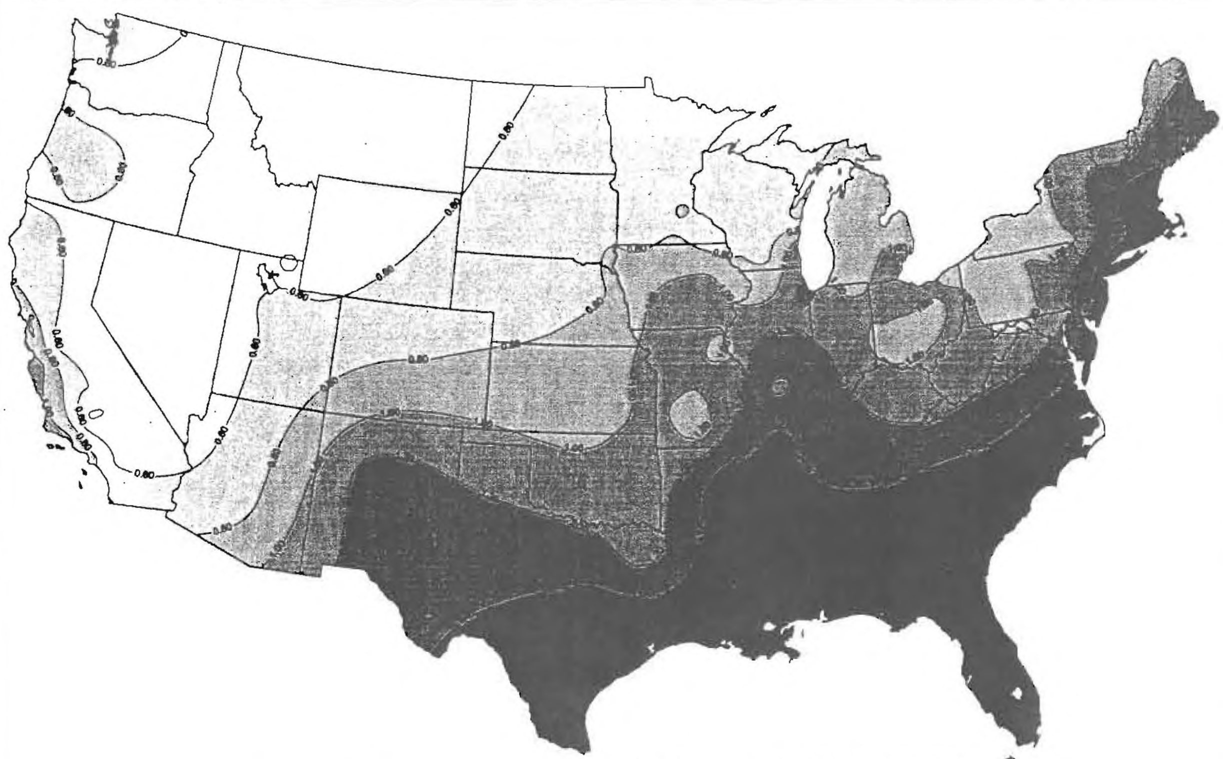

Figure 6. USDSS Model-Generated Class II Price Differentials ($/cwt @ 3.5% fat and 8.62% snf), May 1995

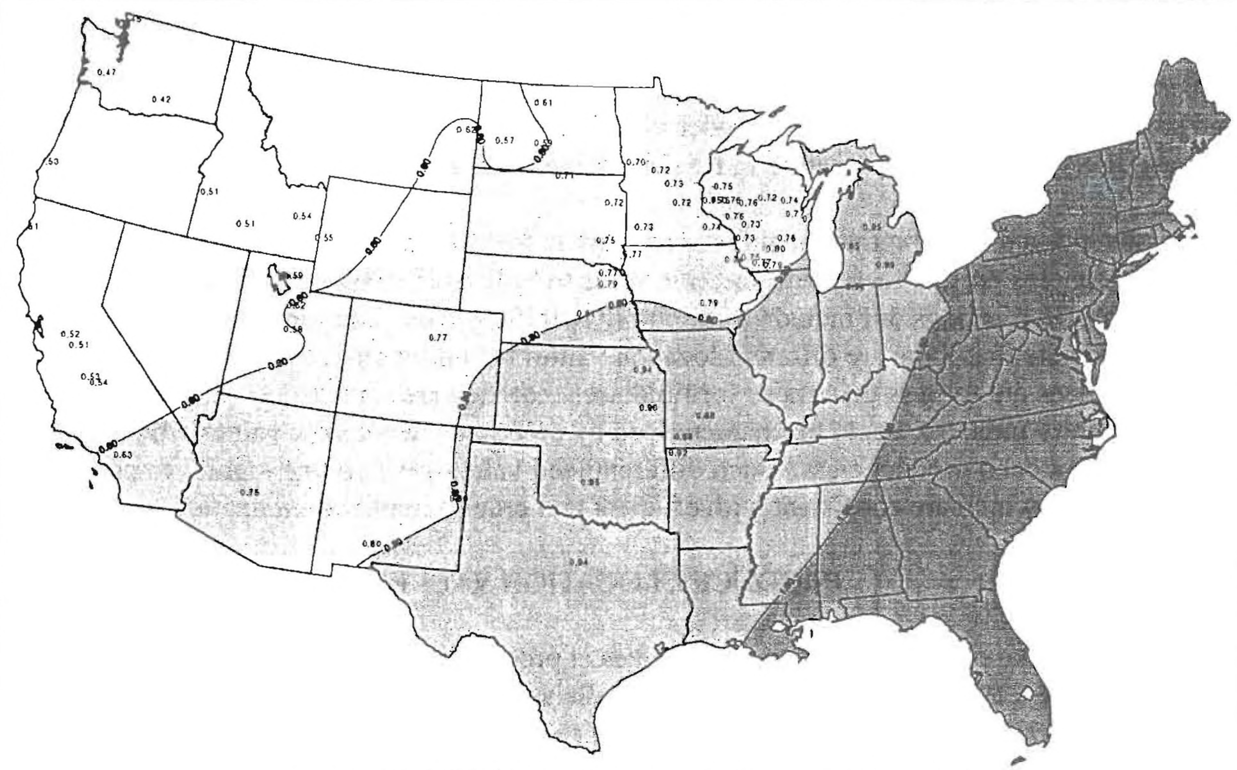

Figure 7. USDSS Model-Generated Cheese Differentials ($/cwt @ 3.5% fat and 8.62% snf), May 1995

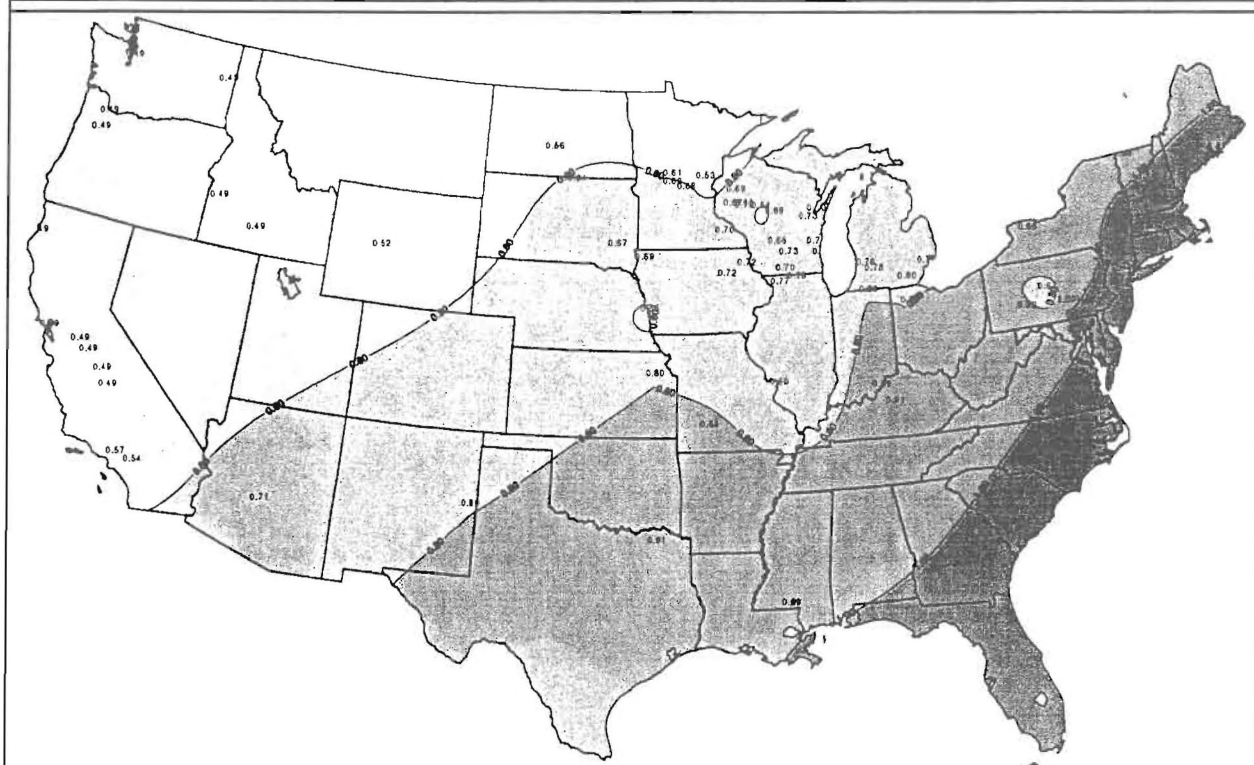

Figure 8. USDSS Model-Generated Butter/Powder Differentials ($/cwt @ 3.5% fat and 8.62% snf), May 1995

found in Pennsylvania, Maryland, and Maine. There are no cheese processing locations found in the Southeast in the optimal solution. Figure 8 and Table 2, column 3, indicate that location values of milk at butter-butter/powder locations has a range of almost 60 cents. As with cheese and soft products, the lowest butter/powder values are found in the northwest and the highest in the east. USDSS chose one location in Louisiana, also with a relatively high value.

Conventional wisdom that manufactured dairy product markets are 'national' in scope has led to the conclusion that there is no location value to milk used in such products, although the more recent III-A rulings did include locationally specific prices. The foregoing results from this analysis indicate that there are different location values for milk used in manufactured products. The differences are far less than those for fluid uses, but they are significant. An optimally organized dairy industry would be characterized by processing level milk values which differed by location for each product class. Such differentiated values give pricing signals to producers and processors which are consistent with efficient and orderly market organization.

PRODUCER LOCATION VALUES

In addition to providing relative milk values at processing locations, the optimal solution to USDSS for May, 1995 yields shadow values at milk supply locations. These can be interpreted in the same way as the processing shadow values, i.e., a 100 pound change in the availability of milk at a particular supply point results in a change in the optimal objective value which is equal

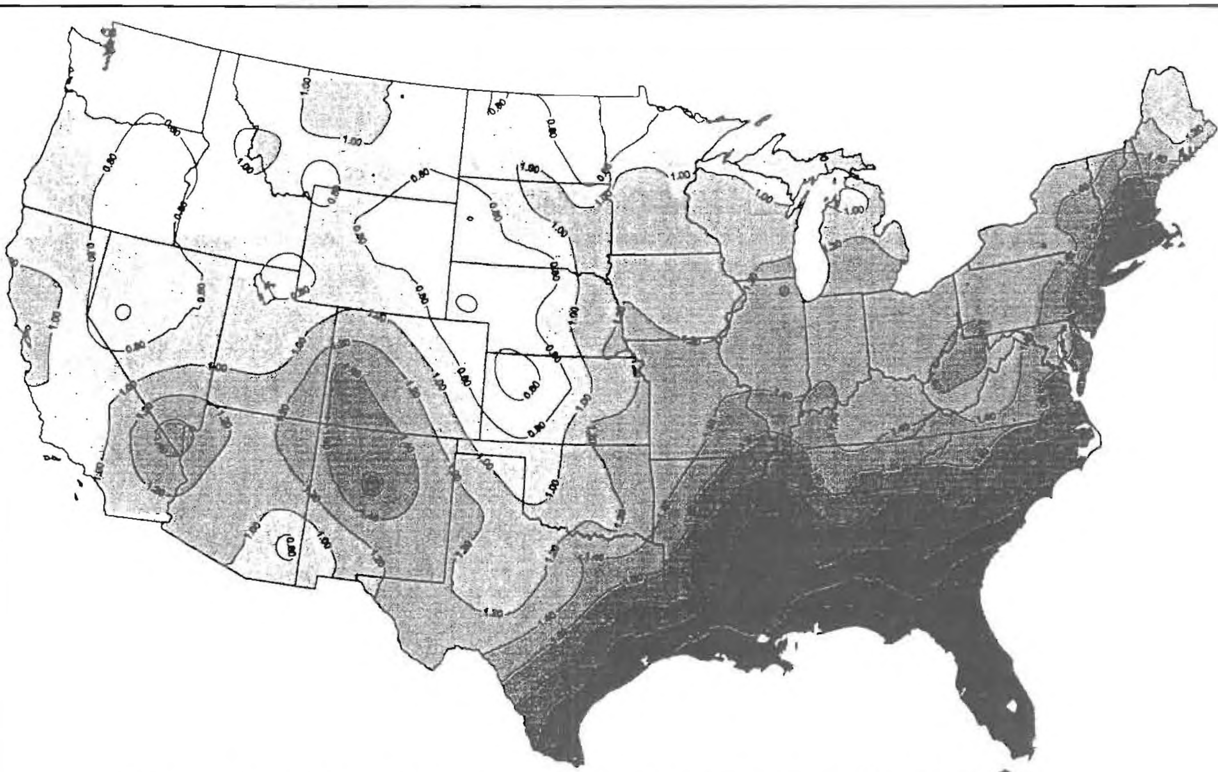

Figure 9. USDSS Model-Generated Farm-Point Milk Price Differentials ($/cwt @ 3.5% fat and 8.62% snf), May 1995

to the appropriate shadow value. Because of the multi-component nature of USDSS, however, the shadow values for supply points obtained directly from the solution are for milk at local butterfat (fat) and solids-not-fat (snf) tests. In the following analysis, these shadow values, which are expressed as $/cwt. at supply points, are standardizeded to a 3.5% at and 8.62 percent snf milk equivalent. Table 3, column 1, and Figure 9 indicate these standardized shadow values of milk at supply points. Unlike the fluid values, no constant adjuster is added to these USDSS simulated values. These values indicate the 'system-wide' valuation of milk resources at supply locations. 'System-wide' in the sense that all dairy product consumption and all dairy product processing opportunities are considered. By selecting the lowest valued areas to have the same color as the lowest valued areas in Figure 3, the revenue-adjusted class I value surface, it can be seen that the supply surface is very similar, but not identical, to the simulated class I value surface. At any particular fluid processing location, there are a set of opportunities available to use interplant movements of milk components, mainly fat, which are in excess of local fluid needs. Fluid plants, which are only allowed to receive producer milk, must balance these excess component receipts. If another 100 pounds of producer milk were to materialize at such a fluid location, these 'balancing' opportunities determine the relative value of that producer milk. Another one hundred pounds of producer milk originating at a similarly located supply point, however, has a different set of alternative uses. It could move to that local fluid plant at which it would face the same opportunities as if it originated at that fluid plant, it could move to a distant fluid plant, at which it would face the same type of opportunities, but face different balancing opportunities and costs, or it could move to a local or distant manufacturing plant at which it would face a very different set of opportunities. The type of plant and the location to which a local supply moves are very important in determining that local supply's relative value.

Blending and Pooling

In USDSS, supply point shadow values equilibrate such that there is only one value attained at each supply point regardless of the optimal destination and use of that supply point's milk; local or distant, fluid or manufacturing. In a very real sense, USDSS shadow prices at supply points are blended values which reflect values considering all product use opportunities. If the U.S. consisted of a single FMMO regulated market, it is conceivable that class prices paid by individual processing units could follow the value surfaces described in Figures 3 and 6-8, and Table 1, column 3, and Table 2, columns 1-3, and the blend price surface could follow the value surface described in Figure 9 and Table 3, column 1. Under a plant-point system, processing plants of each class would be responsible to the pool at those class values stipulated at each of their respective locations described above. Adjustments for transshipped components and their final use classification would be made. On the producer side, adjustments to supply location blend prices would be made on the basis of the originating supply location and the destination of the plant of first receipt. The difference between the supply values at these two locations would determine the adjustment to the producer blend price. Moving up in relative supply values would warrant an upward adjustment in blend price and moving down in relative supply values would bring a downward adjustment. These price schedules give processors incentives to chose plant locations and activities consistent with efficient industry organization. Milk producers are given incentives to ship their milk in accordance with the efficient movements determined by the USDSS solution.

Currently, there are 31 FMMO areas. USDA is mandated by the 1996 farm bill to consolidate these areas into ten to fourteen areas. The current USDA proposal is 11 consolidated orders. If there is more than one order, the pricing system described above potentially breaks down. This happens because of pooling. If the optimal processor level price surface is followed, proper processor incentives can be maintained. However, producer incentives to maintain optimal market flows of milk to processors cannot be guaranteed. By defining geographic market areas and pooling the receipts with these areas, optimal supply point prices may no longer coincide with those prices which would be necessary to maintain efficient spatial allocations of milk. This happens because the base, market level blend price for two nearby supply points, whose plants of first receipt happen to fall in different order areas, could differ because of differences in market-wide utilization in addition to location based value differences. This is, to a large extent, an issue of border price misalignment. If a system of blend price adjustments can be found whereby border price misalignment can be attenuated, then producers could be given a set of incentives which is consistent with efficient market organization.

SENSITIVITY OF CLASS PRICE SURFACES

As was noted previously, the May, 1995 and October, 1995 base solutions differ with respect to their revenue-adjusted differential structures. These 'seasonal' differences do not appear to be of a magnitude which would suggest that class I differential levels be revisited seasonally. Other available market order mechanisms, such as seasonal transportation credits, might be more appropriate for addressing these short-term, fluctuating needs. No doubt, however, there would be other naturally occurring changes which, over time, would necessitate more permanent realignment of the differentials. Of course, significant changes in milk and dairy product transportation costs or technologies could alter the differential surface directly through an impact on the cost of alternative sources of milk and dairy products. Also, changes in the spatial dispersion of milk supplies and/or dairy product demands could alter the differential surface. Would annual review and readjustment be necessary? Maybe biannually would be more appropriate? Would decennially be sufficient? After all, the current levels were implemented well over 10 years ago. To discern the impacts of spatial trends in population and milk production, two sets of experiments were conducted using USDSS.

In Experiment #1, census of population estimates of Total Resident Population of States at five-year intervals between 1960 and 1995 were used to reallocate estimated 1995 dairy product demand among the 334 consumption points in USDSS. By computing the relative share of population at each consumption point in each year, 1995 consumption can be reestimated for each consumption point for each year. Total 1995 consumption levels are maintained, but are simply rearranged around the U.S. in accordance with spatial population distributions for years prior to 1995. In this manner, we can isolate the impacts of spatial shifts in population over time. In a similar fashion, 1995 milk supply at each of the 240 supply locations was reallocated based on the estimated 1960 milk production for each state. As with consumption, relative shares of milk production are computed for 1960 and these are then used to redistribute the 1995 level of milk supply to the supply locations, maintaining 1995 total milk supply levels, but again simply rearranging these supplies around the U.S. in accordance with a spatial milk production distribution for 1960.

For Experiment #1, eight solutions of USDSS were generated. All use the 1960 spatial distribution of milk supplies and each one corresponds to one of the population distributions derived at five-year intervals from 1960 to 1995. For each solution, a set of revenue-adjusted differentials was computed in the same manner as specified earlier. In this experiment, timewise differences in the calculated differential levels for specific locations are caused solely by the spatial shifting in population and its impact on demand relative to supply at the various demand points. As demand increases or decreases relative to the 1960 distribution, the associated differential will increase or decrease as well. All the geographic population shifts for any particular year are analyzed simultaneously. Table 4 ranks the differentials calculated for each of ten selected cities for the eight population distributions and for the Base solution. The solution cities with the highest and lowest differentials in each year are also reported at the bottom of Table 4.

If the 1960 spatial distribution of supply had been maintained, let's say by government policy, but the historic population shifts did otherwise occur, two notable impacts on calculated differentials are apparent from Table 4. First, the changing rankings for the selected cities through time indicates that over the 35 year time period, population shifts alone were sufficient to significantly alter the relative milk values at consumption locations. Los Angeles, Miami, Phoenix, and Dallas experienced milk value increases. Miami increased by more than $2.00/cwt and Phoenix by more that $1.60/cwt. Boston, New York City, Seattle, Chicago, and Minneapolis experienced milk value decreases. Boston saw a $0.36 decrease in milk value. Atlanta saw essentially no change. Second, while the demand-induced relative milk values at these cities changed substantially for several cities, the relative rankings did not change so dramatically. With the exceptions of Boston and Dallas, the top and bottom five cities remained the same between the 1960 and 1995 demand distributions. Despite an increase of $0.34 in its milk value between 1960 and 1995, Los Angeles dropped from the hishest valued city among the ten selected cities to third, as the large value increases for Miami and Phoenix moved these cities past Los Angeles.

Columns 1 through 4 of Table 4 describe what the calculated revenue-adjusted differentials would have been if population shifts between 1960 and 1995 would have been allowed to occur, but the location of milk production was fixed at 1960. Column 5 of Table 4 describes the same information with 1995 demand *and* supply distributions, i.e., the October 1995 base solution. Compared to column 4 (geographic distributions for 1960 supply and 1995 population), Miami's milk value actually increases by another $0.31. The supply distribution impact for Miami is to increase milk values even more than population alone. In contrast, Phoenix, which had a substantial demand induced value increase between 1960 and 1995, experienced a substantial value decrease when supply shifts between 1960 and 1995 are incorporated. Similarly, Los Angeles, which also had a demand induced value increase, ends-up with a value decrease when supply shift is considered. How could this happen? In 1960, Florida had 2.70% of the U.S. population, while California and Arizona had 8.86% and .74%. These three had 1.15%, 6.74%, and .40% of the U.S. milk supply, respectively. By 1995, Florida, California, and Arizona had 5.43%, 12.10%, and 1.62% of population and 1.54%, 16.37%, and 1.44% of supply. Expressed as ratios of supply to demand shares, the combinations of 1960 and 1995 for Florida, California, and Arizona are presented in Table 5. A ratio of 1 would indicate a balance between supply and demand. A ratio less than 1 indicates deficit and greater than 1 indicates surplus.

All three states show an increasing deficit when the 1960 geographic demand structure is compared to 1995, holding supply shares at 1960 levels. Each state's supply to demand ratio decreases from column 1 to column 2. It would not be unreasonable to expect that relative milk values in these states would increase under these same circumstances, and possibly dramatically, give the magnitudes of the changes in ratios. When we consider 1995 demand and 1995 supply geographic structure, Florida's ratio remains very nearly the same as with 1995 demands and 1960 supply. The ratios for California and Arizona, however, increase dramatically. So much so, that California changes from a deficit to a surplus state and Arizona's ratio more than triples to where it is much closer to being balanced. Of course, states are not the same as cities. Milk serving the ten selected cities does not necessarily come from the same state in which the city is located. This would be particularly true for New York City, Boston, and Chicago, but would also be true for the others as well. To the extent that the state supply shifts represent the relevant milk sheds for each city, this type of exercise does reveal why some cities see substantial milk value increases and others smaller increases or even decreases. Judging from the demand impacts alone, it is reasonable that system-wide class I differential alignment should be evaluated at least at five year intervals. Based on these selected cities, we find demand induced values changes alone which are as much as $0.87/cwt within a five-year interval.

Experiment #2, like #1, considers timewise shifts in population, given a specific spatial distribution of supply. The October, 1995 base distribution of milk supply at each of the 240 supply locations is maintained for each of four solutions generated for experiment #2. Each solution corresponds to a future year for which the Bureau of the Census has projected State Total Resident Populations. These State population projections are used to compute relative shares at each consumption location for each projected year. Total 1995 consumption levels, again, are maintained, but are simply rearranged among the consumption points in accordance with the population projections. In this manner, the impacts of projected future shifts in population on the calculated differentials can be isolated.

Column 1 of Table 6 gives the base October 1995 solution values. Columns 2 to 5 give the model-generated, revenue-adjusted class I differentials using 1995 supply and population projections for 2000, 2005, 2015, and 2025. As with the historic population analysis of experiment #1, the rankings of the ten selected cities change. Most notably, Los Angeles, with a $1.84 value and a rank of 9 in the base October 1995 solution, experiences a demand induced increase of $0.62 to $2.46 and a corresponding change in rank to 6. Minneapolis moves from a rank 7 to 10 with only a $0.02 decrease in value. Seattle moves from 10 to 9, but has an increase of $0.32 and Phoenix keeps the same rank, but sees a $0.20 increase. Miami and Thief River Falls remain the highest and lowest valued cities for all solutions. The largest intersolution change among these 10 selected cities is $0.36 for Los Angeles. As in experiment #1, these changes do not include any impacts of changes in the geographic distribution of supply. For any particular city such changes could enhance or diminish the demand impacts. Again, we would judge these demand-induced changes alone to be of sufficiently large enough magnitudes to warrant revisiting class I differentials on a periodic basis.

MINIMUM THROUGHPUT SOLUTION

All of the solutions presented to this point in this publication have imposed only mild restricts on USDSS plant locations. That is, information on the locations of actual dairy processing plants is used only to identify potential geographic locations which are eligible to process any of the five product types. No restrictions are placed on the maximum or minimum receipts at those locations. Subsequent to the initial USDSS solutions, which reported calculated differentials, questions began to emerge concerning the issue of accounting for current plant operations, e.g., locations and processing volumes, in the USDSS optimally calculated differentials; i.e., the extent to which current plant operations should be considered in determining the class I differentials. Of course, at least two points of view on this issue exist; 1) that current fluid milk operations should not be considered and only the set of optimal fluid plant locations and sizes warrants economic consideration and 2) that existing fluid milk operations developed at least in partial response to previous regulatory rules and this behavior needs to be recognized in any new rule. A third experiment was conducted with USDSS to assess the impact on the calculated differentials of imposing current (1995) fluid plant operations locations and sizes.

As described in the model documentation, while there were over 1,300 individual dairy processing facilities identified for the base period, the city locations represented by these plants were reduced to 434 cities at which processing of one type of dairy product or another could take place. There were 319 cities identified as potential fluid processing cities. No all-encompassing source of processor information exists for the US. Various sources of information were used to assemble the processing locations data and these sources gave little or no information about plant size, or, 'throughput'. The first step in the 'minimum throughput' experiment was to assign total route disposition information which was made available to us by USDA to the cities available in USDSS. USDA's Agricultural Marketing Service, Dairy Programs Office assembled such data in the form of 'Total Route Disposition' and 'Bulk Physical Receipts' for October, 1995 for plants which it could identify. Since some of the identified plants were not regulated, no estimates of either route disposition or bulk receipts were available for these plants. These included plants for the entire state of California. For those cities where USDA had no information about the size of a known plant or did not list an unregulated plant which was known to exist, other sources of information were employed to estimate that plant's volume. After all assignments and volume estimates were completed, 285 cities were assigned 'minimum throughputs' for fluid processing. That is, a lower bound on the volume processed at each of these cities was specified. These were the minimum volumes which USDSS would require a particular plant location to process. We estimated that this procedure accounted for 95% of U.S. total fluid milk processed in May of 1995. Figure 10 shows the 285 cities representing fluid milk processing in the Minimum-Throughput case. The relative size of the triangles represents the minimum requirements at each city. Again, it must be remembered that these locations often represent the aggregate location of several fluid processing plants.

Figure 10. 285 Fluid Plant City Locations Used in Minimum Throughput Analysis: Size of Triangles Indicates Relative Values

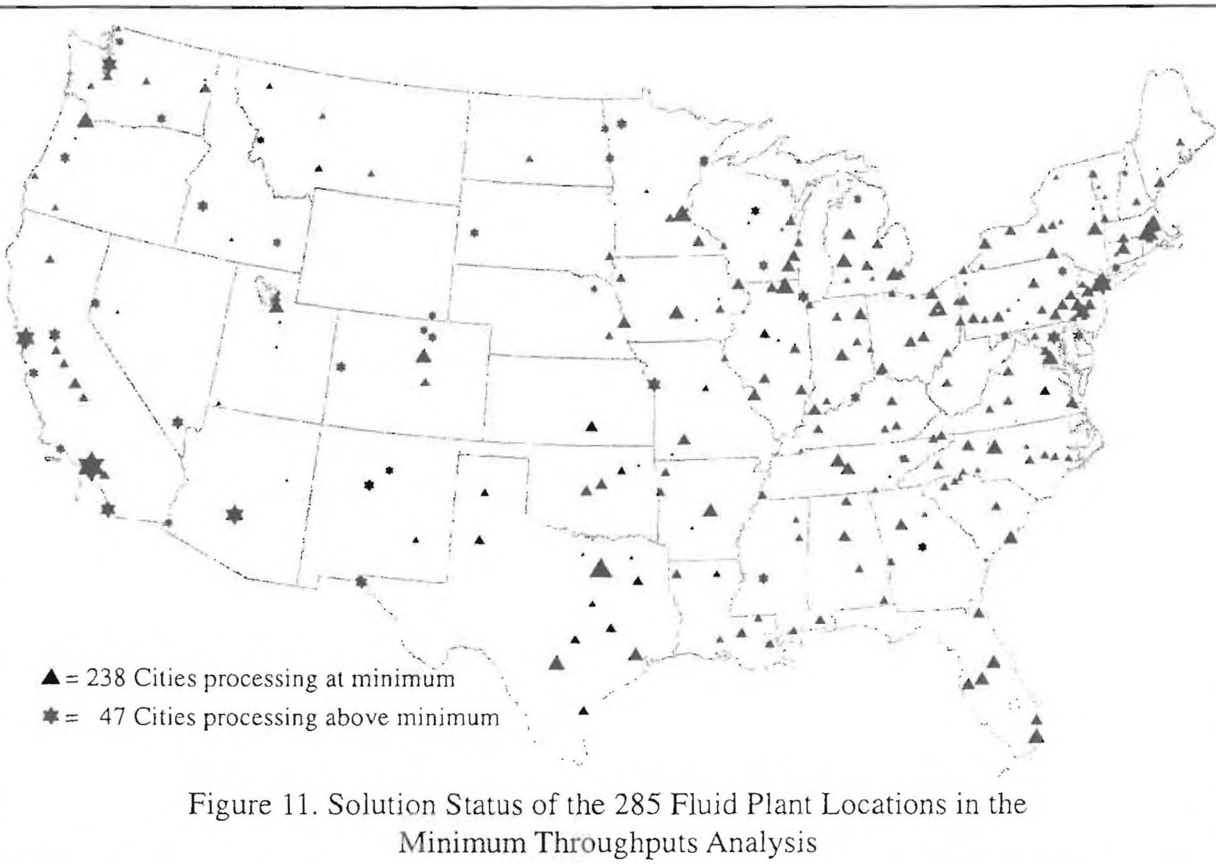

Figure 11. Solution Status of the 285 Fluid Plant Locations in the Minimum Throughputs Analysis

Once the minimum throughputs were established for the 285 fluid processing cities, the May 1995 base was rerun for an optimal solution which required that at least the minimum flows of milk pass through the identified cities. All other cost parameters; assembly, interplants, and distribution, remained the same, as did the locations and sizes of milk supplies and dairy product demands. Based on this new, additional information, optimal flows and shadow values were derived by USDSS in the same manner as in all the other solutions described earlier. Revenue neutral differentials were computed from those shadow values.

Figure 11 depicts the optimal fluid plant sizes when minimum fluid throughputs are required. Each location with a triangle is operating, in the optimal solution, at a level equal to the minimum level specified above. That is, USDSS determined that locations with triangles should be operated at no more than the minimum required processing levels. Locations with stars are operating at levels above the minimums. That is, because the total minimum flows to fluid plants accounted for only 95% of the processing which was needed, USDSS was free to allocate the remaining 5% to plant locations in an optimal manner. City locations indicated by stars are cities to which USDSS determined additional fluid milk processing, over and above the minimum levels, should be allocated in order to minimize costs. The size of these stars indicate the relative size of such locations. The fact that these stars are dispersed across the country indicates that the procedure for determining minimum required flows described above did not create any significant spatial biases with respect to minimum flows versus demand.

Figure 12 and Table 8, column 4 (labeled MIN_THRU), report these 'revenue-adjusted' class I spatial values for the 214 cities which processed fluid milk in both the base May 1995 and in the Minimum Throughput scenarios. Column 3 (labeled RNDIFF) reports the base May, 1995 solutions values for these cities and column 5 reports the difference between the base and Minimum Throughput values. Looking at Figure 12, it can be seen that the general spatial pattern of prices for the Minimum Throughput solution follows the Base May 1995 pattern; generally lower values in the upper midwest, northwest, and west coast, and increasing values to the southeast and east. Again the increases are not nearly as large as transportation costs and the general levels and ranges are similar to the Base May 1995 solution with Miami being the city with the highest calculated value, at $5.19 and Thief River Falls, Minnesota being the lowest value city at $1.44. However, despite the similarity in the overall surface between the Minimum Throughput solution and the Base, individual locations experience significant changes. The largest increase is $0.80 in Bozeman, Montana and the largest decrease is $0.30 in Grand Junction, Colorado. Three locations in Montana see an increase of $0.39 or more, while all five locations in Georgia experience decreases of $0.22 or more. Not so small changes can be identified throughout every region. Portland, Maine increases $0.05, while Boston, Massachusetts decreases $0.06 and Hartford, Connecticut decreases $0.13. Miami, Florida increases $0.11, while Atlanta, Georgia decreases $0.26. Chattanooga, Tennessee decreases by $0.12, while Bristol and Kingsport, Tennessee increase by $0.24 and Nashville increases by $0.11.

Basically, requiring that the potential choices of fluid plant locations reflect estimates of actual throughput for 1995 does not alter the overall price surface substantially. It does, however, change the values at some individual city locations significantly. By requiring fluid to be processed at locations which USDSS would not have otherwise chosen to minimize costs, milk

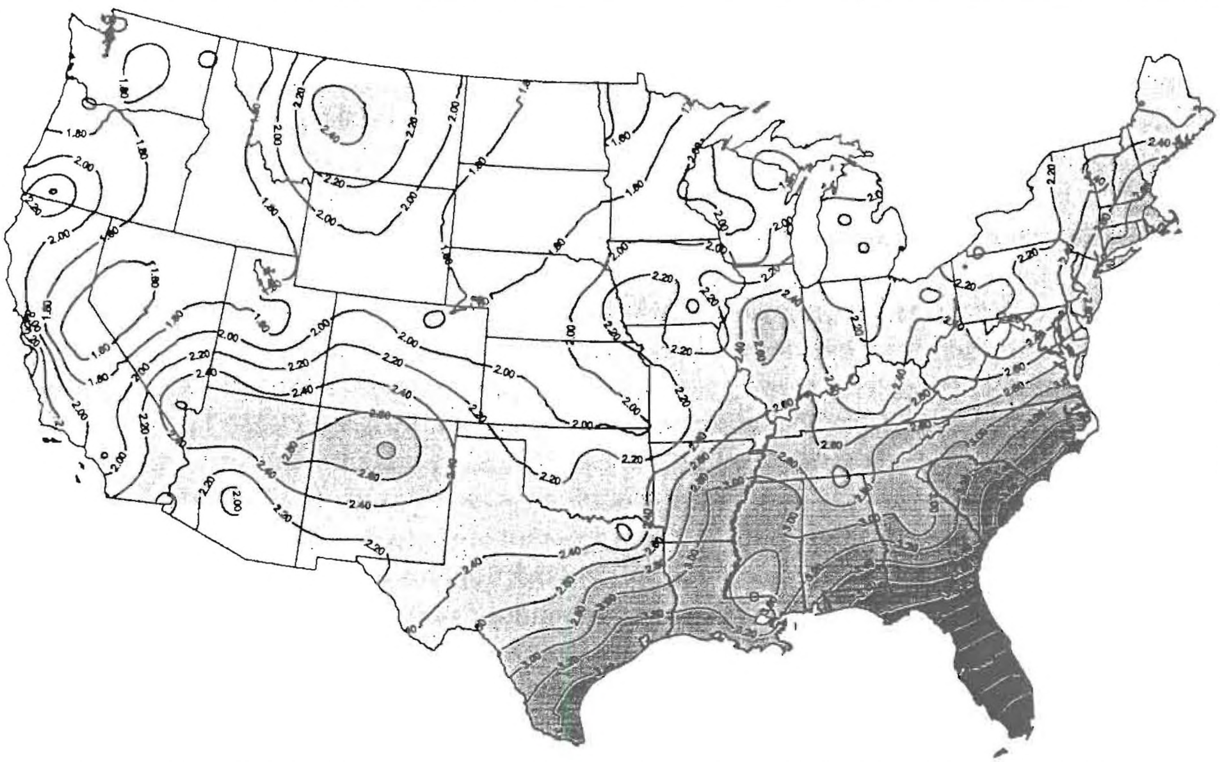

Figure 12. USDSS Model-Generated Revenue-Adjusted Class I Price Differentials ($/cwt @ 3.5% fat and 8.62% snf), Minimum Throughputs at 285 Fluid Processing City Locations, May 1995

in the vicinity of such plants becomes relatively dearer, such as in Montana. Because of revenue-neutrality, the totality of values at other locations must decrease. To the extent that other locations are likewise forced to behave non-optimally, they will maintain their values or, if their actual flows are similar to the USDSS determined optimum flows, they will experience decreases.

CONCLUSIONS

When considering the issue of spatial values for milk and milk components, the appropriate question is 'how much different the values should be' rather than 'should they be different'. Using a spatially disaggregated model of the U.S. dairy sector, the results of our analysis demonstrate that, under conditions which prevailed in May and October of 1995, milk produced in the U.S. had distinct location values at geographically dispersed points of processing. When May, 1995 milk supplies are optimally utilized in dairy product processing and the costs of milk and dairy product flows are minimized for the entire U.S. dairy sector, standardized milk values at fluid processing locations differ by $3.63 from the lowest to the highest value locations. This is more than the difference currently found in Federal Milk Marketing Order minimum class I prices. While the range in these model-generated values is larger than current actual class I differentials, the weighted average dispersion is smaller, i.e. , the model-generated value surface has higher peaks, but is flatter overall.

When compared to the current actual class I differentials, we find May, 1995 model-generated values which are higher, lower, and about the same in various parts of the country. Generally speaking, from the upper midwest as far east as Ohio and down through Missouri into western Tennessee and northeast Arkansas current class I differentials are lower than model-generated class I values. Florida, the four-corners area west to Las Vegas, and a narrow region along the Pacific coast from southern Oregon to central California also have current differentials which are lower than model-generated values. Areas with higher current differentials run from northern Washington, through Montana and Wyoming, eastern Colorado and western Kansas, including all of Oklahoma and Texas, as well as southern New Mexico and Arkansas and western and southern Louisiana. A second area covers all of New England, southeastern New York, eastern Pennsylvania, all of Virginia and Maryland, and much of North Carolina. These differences between current actual class I differentials and model-generated values indicate that the current actual differentials at various locations range from $1.72 too high to $1.21 too low. Similar results are obtained for analysis of October, 1995 with slight differences reflecting seasonal milk supply and demand conditions. The small magnitude of these seasonal differences could be accommodated by FMMO provisions other than changing class I differentials.

The large magnitude of the differences between actual differentials and model-generated values could be attributed to at least two conditions. 1) Many of the areas where current differentials are determined to be too high are areas of the country which fall under state milk regulatory agencies. It's quite likely that these agencies err on the side of establishing minimum values above those which are justified when considered in a broader geographic context. 2) There have been few systematic attempts to align system-wide class I differentials since the concept of system-wide alignment was first used in the 1960's. It may well be that the entire set of class I differential values needs to be reconsidered more often. Using the spatial model, two experiments were conducted to assess the impacts of past and projected population shifts alone on the spatial value of milk. These experiments indicate that spatial shifts in population alone are of large enough magnitudes that the system-wide set of class I differentials should be reconsidered at least every five years in order to avoid situations where extremely large adjustments are needed to realign these values.

Given the magnitude of the adjustments currently needed in some areas of the country, the issue arises as to whether or not the levels of current class I plant operations should be considered in the determination of the optimal, model-generated values. This is as much an equity consideration as an efficiency one. To obtain a measure of the difference such a consideration would make, a solution of the spatial model was obtained where our best estimates of aggregated fluid milk throughput at eligible fluid processing cities was required. While the overall price surface looked much like the one obtained without requiring that current processing volumes be reflected in the optimal solution, individual processing locations experienced substantial differences. Twenty-three of the 285 fluid processing locations had model-generated values which were $0.20 or more higher in the case where current processing volumes were protected compared to no processing volume requirements. One such location was $0.80 above. Twelve of the 285 fluid processing locations had volume protecting values which were $0.20 or more lower than in the no volume requirement case. One-hundred and fifty-nine of the 285 fluid processing locations had volume-based values less than $0.10 different than in the no volume case. The volume requirement class I values may provide indications of an intermediate step toward full adjustment of the misaligned values which accommodates past plant location and size decisions.

The same spatial analysis which generated the values for class I milk at the various geographic locations also generates disparate values for milk used in class II, cheese, and butter/powder. While these values do not differ as much as class I values, the spatial differences are not trivial. The range from high to low for class II is $1.41 in May, 1995, for cheese, $0.71, and for butter/powder, $0.58. Such magnitudes would be considered substantial in class I terms. While there is no doubt that these manufactured products trade over much larger areas than is generally true for fluid products and one may feel comfortable describing these markets as 'national' in scope, spatially different milk and component values still exist. We may speak of national markets for oranges or grapefruits, for lettuce, or even for maple syrup, but it does not necessarily follow that there is one national price.

USDSS knows nothing of FMMO marketing areas. In fact, it knows nothing of any other FMMO rules including the practice of market-wide pooling. The farm milk values generated by the model presume, in fact, that there is one federal order market. In this way, these farm values are consistent with the plant values generated for all classes even though the value surface is unlike any specific class. USDSS does not generate farm-level value differences which are the same as the generated class I value differences, even for one national market. Adjusting spatial farm-level prices the same as class I prices creates incentives which are not consistent with the optimal, least-cost industry organization. When multiple FMMO markets are considered, the problem becomes worse, especially for milk supplies located near the borders of the marketing areas. In the 1990 Food, Agriculture, Conservation, and Trade Act, Title 1, Section 113, congress specifically authorized "... that adjustments in payments by handlers under paragraph (A) need not be the same as adjustments to producers under paragraph (B)...", thus opening the possibility of adjusting class and blend prices differently. This option should be seriously considered by USDA when designing a system to provide orderly, efficient pricing incentives to producers and plants.

Finally, the results from USDSS were not intended to give specific milk and component values for each and every county location in the country, but to give guidance with respect to relative, system-wide levels more generally. Despite the high level of disaggregation embodied in USDSS, using it's results to speak to milk value differences between counties may be asking too much. There are 3,111 counties in the U.S. there are only 622 distinct geographic points represented in USDSS, a ratio of 1 geographic point for each five counties. For a similar study of the New York-New Jersey FMMO, which encompassed 176 counties, we used 208 geographic points, a ratio of more than 1 geographic point per county. An especially acute problem arises with respect to milk supplies, where 240 points represent the supply from 3,111 counties; 1 point for each 13 counties. In the New York-NJ study, 98 supply points represented the 176 counties; 1 point for each 1.8 counties. If county-level milk and component values are desired from USDSS, something more like 1,500 supply points would need to be specified rather than the current 234. This is within computational capabilities of today's hardware and software.

Table 1. Actual, Eau Claire, WI Plus Transportation Cost, and USDSS Model-Generated Class I Values at U.S. Geographic Locations.

			"Class I Differentials, $/cwt."				Differences	
			Actual	Eau Claire	Revenue-Adjusted		Revenue-Adj'd - Actual	
City	State	F/S/U[1]	1995	plus TC[2]	May '95	Oct '95	May '95	Oct '95
Birmingham	AL	F	3.08	4.70	2.96	3.23	-0.12	0.15
Dothan	AL	F	3.58	5.43	3.64	3.93	0.06	0.35
Hartselle	AL	F	2.83	4.44		2.97		0.14
Huntsville	AL	F	2.83	4.35	2.61	2.90	-0.22	0.07
Mobile	AL	F	3.58	5.51	3.63	3.88	0.05	0.30
Montgomery	AL	F	3.28	5.05	3.30	3.57	0.02	0.29
Fayetteville	AR	F	2.55	3.87	2.07	2.02	-0.48	-0.53
Fort Smith	AR	F	2.77	4.10	2.30	2.24	-0.48	-0.53
Little Rock	AR	F	2.77	4.36	2.73	2.71	-0.04	-0.06
Phoenix	AZ	F	2.52	8.01	1.88	1.85	-0.64	-0.68
Yuma	AZ	F	2.37	8.70	2.46	2.41	0.09	0.04
Fresno	CA	S	1.80	9.24	1.64	1.39	-0.16	-0.41
Los Angeles	CA	S	2.07	8.90	1.95	1.84	-0.12	-0.23
Merced	CA	S	1.80	9.03	1.64	1.58	-0.16	-0.22
Modesto	CA	S	1.80	8.87	1.65	1.55	-0.15	-0.25
Redding	CA	S	1.80	9.00	2.13	1.89	0.33	0.09
Salinas	CA	S	1.80	9.37	2.55	2.21	0.75	0.41
San Diego	CA	S	2.07	9.12	2.16	2.04	0.09	-0.03
San Francisco	CA	S	1.80	8.94	2.09	1.76	0.29	-0.04
Santa Barbara	CA	S	2.07	9.29	2.25	2.13	0.18	0.06
Stockton	CA	S	1.80	8.76	1.76	1.44	-0.04	-0.36
Visalia	CA	S	1.80	9.23	1.76	1.58	-0.04	-0.22
Yuba City	CA	S	1.80	8.76	2.02	1.69	0.22	-0.11
Colorado Springs	CO	F	2.73	4.93	2.13	2.08	-0.60	-0.65
Denver	CO	F	2.73	4.74	1.91	1.86	-0.82	-0.87
Fort Collins	CO	F	2.63	4.65	1.84	1.80	-0.79	-0.83
Grand Junction	CO	F	2.00	5.70	2.54	2.46	0.54	0.46
Greeley	CO	F	2.63	4.53	1.73	1.69	-0.90	-0.94
Bridgeport	CT	F	3.14	5.49	3.01	2.97	-0.13	-0.18
Hartford	CT	F	3.14	5.62	2.84	2.80	-0.30	-0.34
Dover	DE	F	2.91	5.08	2.59	2.53	-0.32	-0.38
Deerfield Beach	FL	F	4.18	7.18	4.95	5.24	0.77	1.06
Jacksonville	FL	F	3.58	6.08	4.13	4.41	0.55	0.83
Lakeland	FL	F	3.88	6.77	4.56	4.97	0.68	1.09
Miami	FL	F	4.18	7.33	5.08	5.36	0.90	1.18
Orlando	FL	F	3.88	6.63	4.51	4.92	0.63	1.04
Sarasota	FL	F	3.88	6.90	4.75	5.16	0.87	1.28
Tampa	FL	F	3.88	6.69	4.57	4.99	0.69	1.11
Athens	GA	F	3.08	5.04	3.17	3.42	0.09	0.34
Atlanta	GA	F	3.08	4.77	3.26	3.52	0.18	0.44
Columbus	GA	F	3.28	5.22	3.47	3.73	0.19	0.45
Macon	GA	F	3.18	5.08	3.14	3.41	-0.04	0.23
Savannah	GA	F	3.40	5.73	3.63	3.93	0.23	0.53
Cedar Rapids	IA	F	1.48	1.99	2.34	2.31	0.86	0.83
Des Moines	IA	F	1.55	2.10	2.27	2.24	0.72	0.69
Dubuque	IA	F	1.36	1.69	2.01	1.98	0.65	0.62
Elkader	IA	F	1.20	1.85	1.87	1.84	0.67	0.64
Iowa City	IA	F	1.48	2.10	2.27	2.23	0.79	0.75

Table 1. (Continued)

City	State	F/S/U[1]	"Class I Differentials, $/cwt." Actual 1995	Eau Claire plus TC[2]	Revenue-Adjusted May '95	Oct '95	Differences Revenue-Adj'd - Actual May '95	Oct '95
Le Mars	IA	F	1.75	2.34	2.03	1.98	0.28	0.23
Boise	ID	F	1.50	6.67	1.69	1.62	0.19	0.12
Coeur d'Alene	ID	F	1.90	6.26	1.75	1.58	-0.15	-0.32
Pocatello	ID	F	1.65	5.79	1.75	1.70	0.10	0.05
Shelley	ID	F	1.60	5.62	1.68	1.63	0.08	0.03
Bloomington	IL	F	1.75	2.44	2.56	2.49	0.81	0.74
Carlyle	IL	F	1.92	3.16	2.28	2.21	0.36	0.29
Champaign	IL	F	1.75	2.62	2.37	2.30	0.62	0.55
Chicago	IL	F	1.40	2.14	2.46	2.42	1.06	1.02
East Saint Louis	IL	F	2.01	2.99	2.46	2.38	0.45	0.37
Moline	IL	F	1.48	1.98	2.33	2.30	0.85	0.82
Olney	IL	F	1.92	3.07	2.25	2.18	0.33	0.26
Peoria	IL	F	1.61	2.29	2.65	2.57	1.04	0.96
Quincy	IL	F	1.75	2.58	2.10	2.03	0.35	0.28
Rockford	IL	F	1.31	1.82	2.10	2.06	0.79	0.75
Evansville	IN	F	2.11	3.36	2.44	2.50	0.33	0.39
Fort Wayne	IN	F	1.80	2.72	2.12	2.08	0.32	0.28
Gary	IN	F	1.55	2.22	2.30	2.26	0.75	0.71
Holland	IN	F	2.11	3.34	2.33	2.39	0.22	0.28
Indianapolis	IN	F	1.90	2.83	2.32	2.34	0.42	0.44
Muncie	IN	F	1.90	3.02	2.22	2.25	0.32	0.35
Rochester	IN	F	1.80	2.56	2.16	2.13	0.36	0.33
Warsaw	IN	F	1.70	2.57	1.99	1.96	0.29	0.26
Wichita	KS	F	2.30	3.61	2.05	1.98	-0.25	-0.32
Covington	KY	F	2.11	3.22		2.32		0.21
London	KY	F	2.26	3.79	2.30	2.53	0.04	0.27
Louisville	KY	F	2.11	3.28	2.15	2.20	0.04	0.09
Madisonville	KY	F	2.26	3.55		2.56		0.30
Murray	KY	F	2.39	3.69	2.64	2.63	0.25	0.24
Somerset	KY	F	2.26	3.87	2.16	2.40	-0.10	0.14
Winchester	KY	F	2.11	3.60	2.28	2.32	0.17	0.21
Baton Rouge	LA	F	3.65	5.55	3.17	3.44	-0.48	-0.21
Lafayette	LA	F	3.65	5.75	3.38	3.37	-0.27	-0.29
Monroe	LA	F	3.18	5.23	3.12	3.08	-0.06	-0.11
New Orleans	LA	F	3.65	5.57	3.19	3.46	-0.46	-0.19
Shreveport	LA	F	3.18	5.12	2.71	2.70	-0.47	-0.48
Boston	MA	F	3.24	6.09	3.09	3.05	-0.15	-0.19
Springfield	MA	F	3.12	5.73	2.78	2.74	-0.34	-0.38
Baltimore	MD	F	3.03	4.75	2.34	2.32	-0.70	-0.71
Cumberland	MD	F	2.82	4.42	2.38	2.40	-0.44	-0.42
Frederick	MD	F	3.03	4.66	2.26	2.22	-0.77	-0.81
Bangor	ME	S	3.24	7.00	2.14	2.12	-1.10	-1.12
Lewiston	ME	S	3.24	6.65	2.49	2.46	-0.75	-0.78
Portland	ME	S	3.24	6.51	2.64	2.61	-0.60	-0.64
Detroit	MI	F	1.75	3.19	2.18	2.13	0.43	0.38
Evart	MI	F	1.68	3.17	2.12	2.07	0.44	0.39
Gaylord	MI	F	1.68	2.94	1.70	1.66	0.02	-0.02
Grand Rapids	MI	F	1.70	2.79	2.03	1.98	0.33	0.28

Table 1. (Continued)

City	State	F/S/U[1]	"Class I Differentials, $/cwt." Actual 1995	Eau Claire plus TC[2]	Revenue-Adjusted May '95	Oct '95	Differences Revenue-Adj'd - Actual May '95	Oct '95
Iron Mountain	MI	F	1.15	1.99	1.60	1.54	0.45	0.39
Jackson	MI	F	1.75	2.87	2.13	2.08	0.38	0.33
Kalamazoo	MI	F	1.70	2.64	1.99	1.95	0.29	0.25
Lansing	MI	F	1.75	2.92	2.23	2.18	0.48	0.43
Livonia	MI	F	1.75	3.09	2.09	2.04	0.34	0.29
Saginaw	MI	F	1.75	3.23	2.09	2.04	0.34	0.29
Sault Ste. Marie	MI	F	1.55	2.95	2.06	2.01	0.51	0.46
Duluth	MN	F	1.20	1.52	2.02	1.97	0.82	0.77
Minneapolis	MN	F	1.20	1.20	1.97	1.93	0.77	0.73
Rochester	MN	F	1.20	1.38	1.86	1.83	0.66	0.63
Sauk Centre	MN	F	1.14	1.61	1.77	1.73	0.63	0.59
Thief River Falls	MN	F	1.20	2.38	1.45	1.37	0.25	0.17
Cassville	MO	F	2.19	3.66	2.02	1.98	-0.17	-0.21
Columbia	MO	F	1.68	2.91	2.37	2.29	0.69	0.61
Kansas City	MO	F	1.92	2.84	2.23	2.15	0.31	0.23
Marshfield	MO	F	2.19	3.52	2.02	1.98	-0.17	-0.22
Perryville	MO	F	2.01	3.29	2.42		0.41	
Saint Louis	MO	F	2.01	3.00	2.46	2.39	0.45	0.38
Springfield	MO	F	2.19	3.44	2.09	2.04	-0.11	-0.15
Jackson	MS	F	3.28	4.89	3.22	3.48	-0.07	0.20
West Point	MS	F	3.06	4.62	3.15	3.45	0.09	0.39
Billings	MT	S	2.55	4.33	1.92	2.06	-0.63	-0.49
Bozeman	MT	S	2.55	4.84	1.53	1.67	-1.03	-0.88
Great Falls	MT	S	2.55	5.35	2.11	2.24	-0.44	-0.31
Hamilton	MT	S	2.55	5.80	2.00	2.16	-0.55	-0.39
Asheville	NC	F	2.93	4.62	2.64	2.86	-0.29	-0.07
Charlotte	NC	F	3.08	5.04	2.64	2.97	-0.44	-0.12
Dunn	NC	F	3.23	5.31	3.02	3.31	-0.21	0.08
Goldsboro	NC	F	3.23	5.40	3.09	3.37	-0.14	0.14
High Point	NC	F	3.08	4.91	2.72	3.02	-0.36	-0.06
Kinston	NC	F	3.23	5.51	3.20	3.48	-0.03	0.25
Raleigh	NC	F	3.08	5.20	2.89	3.18	-0.19	0.10
Bismarck	ND	F	1.20	2.84	1.73	1.69	0.53	0.49
Fargo	ND	F	1.20	2.10	1.63	1.55	0.43	0.35
Grand Forks	ND	F	1.20	2.47	1.80	1.71	0.60	0.51
Granville	ND	F	1.20	3.15	1.75	1.71	0.55	0.51
Lincoln	NE	F	1.75	2.90	2.17	2.12	0.42	0.37
Omaha	NE	F	1.75	2.69	2.36	2.30	0.61	0.55
Randolph	NE	F	1.75	2.65	1.89	1.85	0.14	0.10
Concord	NH	F	3.09	6.19	2.81	2.77	-0.28	-0.32
Franconia	NH	F	2.85	6.25	2.49	2.46	-0.36	-0.39
Florence	NJ	F	3.02	5.16	2.65	2.59	-0.37	-0.43
Newark	NJ	F	3.14	5.20	2.76	2.71	-0.38	-0.43
Trenton	NJ	F	3.04	5.22	2.71	2.65	-0.33	-0.39
Wallington	NJ	F	3.14	5.23	2.79	2.74	-0.35	-0.41
Albuquerque	NM	F	2.35	6.23	2.64	2.55	0.29	0.20
Portales	NM	F	2.35	5.58	1.94	1.88	-0.41	-0.47
Santa Fe	NM	F	2.35	5.99	2.87	2.77	0.52	0.42

Table 1. (Continued)

City	State	F/S/U[1]	"Class I Differentials, $/cwt." Actual 1995	Eau Claire plus TC[2]	Revenue-Adjusted May '95	Oct '95	Differences Revenue-Adj'd - Actual May '95	Oct '95
Las Vegas	NV	F	1.60	7.81	2.62	2.49	1.02	0.89
Reno	NV	S	1.64	8.07	1.57	1.45	-0.07	-0.19
Albany	NY	F	2.60	5.48	2.49	2.45	-0.12	-0.15
Binghamton	NY	F	2.55	4.97	2.10	2.07	-0.46	-0.48
Buffalo	NY	S	2.30	4.23	2.17	2.13	-0.14	-0.17
Glens Falls	NY	F	2.47	5.66	2.41	2.37	-0.06	-0.10
Jamestown	NY	F	2.02	4.11	1.95	1.92	-0.07	-0.10
New York	NY	F	3.14	5.24	2.77	2.73	-0.37	-0.41
Rochester	NY	S	2.30	4.57	2.17	2.14	-0.13	-0.16
Syracuse	NY	F	2.35	4.90	2.07	2.05	-0.28	-0.30
Utica	NY	F	2.40	5.12	2.22	2.18	-0.18	-0.22
Canton	OH	F	2.00	3.50	2.15	2.13	0.15	0.13
Cincinnati	OH	F	2.11	3.24	2.22	2.25	0.11	0.14
Cleveland	OH	F	2.00	3.48	2.34	2.30	0.34	0.30
Columbus	OH	F	2.04	3.36	2.35	2.31	0.31	0.27
Mansfield	OH	F	1.90	3.26	2.15	2.13	0.25	0.23
Marietta	OH	F	2.11	3.81	2.35	2.32	0.24	0.21
Ottawa	OH	F	1.80	2.96	1.95	1.91	0.15	0.11
Steubenville	OH	F	2.00	3.80	2.40	2.37	0.40	0.37
Toledo	OH	F	1.80	3.04	2.18	2.13	0.38	0.33
Youngstown	OH	F	2.00	3.68	2.23	2.19	0.23	0.19
Oklahoma City	OK	F	2.77	4.21	2.22	2.15	-0.55	-0.62
Tulsa	OK	F	2.59	3.77	2.24	2.17	-0.35	-0.42
Eugene	OR	F	1.90	8.36	1.89	1.63	-0.01	-0.27
Medford	OR	F	1.82	9.01	2.19	2.09	0.37	0.27
Portland	OR	F	1.90	7.94	1.72	1.58	-0.18	-0.32
Allentown	PA	S	3.09	4.97	2.43	2.38	-0.66	-0.71
Altoona	PA	S	2.00	4.28	2.30	2.25	0.30	0.25
Chambersburg	PA	F	2.91	4.49	2.07	2.06	-0.84	-0.85
Erie	PA	F	2.00	3.88	2.12	2.08	0.12	0.08
Harrisburg	PA	F	2.91	4.67	2.24	2.19	-0.67	-0.72
Johnstown	PA	S	2.76	4.18	2.38	2.34	-0.38	-0.42
Lancaster	PA	F	3.03	4.80	2.26	2.21	-0.77	-0.82
New Wilmington	PA	F	2.00	3.75	2.16	2.12	0.16	0.12
Philadelphia	PA	F	3.09	5.04	2.52	2.47	-0.57	-0.62
Pittsburgh	PA	F	2.00	3.91	2.29	2.25	0.29	0.25
Reading	PA	S	2.94	4.89	2.30	2.26	-0.64	-0.68
Scranton	PA	S	2.74	4.89	2.33	2.29	-0.41	-0.45
State College	PA	S	2.78	4.37	2.15	2.11	-0.63	-0.68
Towanda	PA	S	2.75	4.80	2.07	2.03	-0.68	-0.72
Williamsport	PA	S	2.74	4.55	2.34	2.29	-0.40	-0.45
Providence	RI	F	3.24	5.92	3.14	3.10	-0.10	-0.14
Charleston	SC	F	3.23	5.65	3.45	3.76	0.22	0.53
Greenville	SC	F	3.08	4.85	2.87	3.08	-0.21	0.00
Myrtle Beach	SC	F	3.23	5.81	3.46	3.76	0.23	0.53
Rapid City	SD	F	2.05	3.49	1.64	1.82	-0.41	-0.24
Sioux Falls	SD	F	1.50	2.21	1.97	1.93	0.47	0.43
Bristol	TN	F	2.77	4.54	2.49	2.74	-0.28	-0.03

Table 1. (Continued)

City	State	F/S/U[1]	"Class I Differentials, $/cwt." Actual 1995	Eau Claire plus TC[2]	Revenue-Adjusted May '95	Oct '95	Differences Revenue-Adj'd - Actual May '95	Oct '95
Chattanooga	TN	F	2.77	4.38	2.87	3.13	0.10	0.36
Dresden	TN	F	2.55	3.79	2.67	2.66	0.12	0.11
Kingsport	TN	F	2.77	4.47	2.58	2.83	-0.19	0.06
Knoxville	TN	F	2.77	4.17	2.69	2.91	-0.08	0.14
Memphis	TN	F	2.77	4.10	3.20	3.17	0.43	0.40
Nashville	TN	F	2.55	3.94	2.41	2.69	-0.14	0.14
Alto	TX	F	3.31	5.20	2.72	2.64	-0.59	-0.67
Amarillo	TX	F	2.49	5.13	2.29	2.21	-0.20	-0.28
Austin	TX	F	3.46	5.54	2.67	2.60	-0.79	-0.87
Bryan	TX	F	3.36	5.50	3.15	3.05	-0.21	-0.31
Corpus Christi	TX	F	3.82	6.37	3.49	3.40	-0.34	-0.42
Dallas	TX	F	3.16	4.77	2.47	2.40	-0.69	-0.76
Decatur	TX	F	3.16	4.97	2.23	2.16	-0.93	-1.00
El Paso	TX	F	2.35	6.88	2.10	2.03	-0.25	-0.32
Houston	TX	F	3.70	5.72	3.29	3.19	-0.41	-0.51
Lubbock	TX	F	2.49	5.59	2.38	2.30	-0.11	-0.19
Odessa	TX	F	2.95	5.89	2.60	2.53	-0.35	-0.42
San Antonio	TX	F	3.58	5.84	2.98	2.89	-0.60	-0.69
Sulphur Springs	TX	F	3.16	4.60	2.16	2.10	-1.00	-1.06
Tyler	TX	F	3.16	5.08	2.65	2.57	-0.51	-0.59
Waco	TX	F	3.31	5.13	2.78	2.70	-0.53	-0.61
Provo	UT	F	1.90	6.41	1.76	1.71	-0.14	-0.19
Saint George	UT	F	1.60	7.36	2.54	2.47	0.94	0.87
Salt Lake City	UT	F	1.90	6.27	1.87	1.82	-0.03	-0.08
Charlottesville	VA	S	4.03	4.90	2.31	2.54	-1.72	-1.49
Lynchburg	VA	S	4.03	4.81	2.49	2.71	-1.54	-1.32
Norfolk	VA	S	4.03	5.47	2.91	3.12	-1.12	-0.91
Richmond	VA	S	4.03	5.10	2.55	2.75	-1.48	-1.28
Roanoke	VA	S	4.03	4.67	2.38	2.68	-1.65	-1.35
Strasburg	VA	S	2.90	4.68		2.34		-0.56
Burlington	VT	F	2.50	6.05	2.39	2.35	-0.11	-0.15
Rutland	VT	F	2.65	5.77	2.37	2.35	-0.28	-0.30
Pasco	WA	F	1.75	6.91	1.72	1.67	-0.03	-0.08
Seattle	WA	F	1.90	7.58	1.79	1.67	-0.11	-0.24
Sedro-Woolley	WA	F	1.90	7.63	1.56	1.43	-0.35	-0.47
Spokane	WA	F	1.90	6.38	1.64	1.47	-0.26	-0.43
Appleton	WI	F	1.10	1.53	1.88	1.86	0.78	0.76
Baldwin	WI	F	1.14	1.07	1.86	1.83	0.72	0.69
Green Bay	WI	F	1.12	1.63	1.99	1.92	0.87	0.80
La Crosse	WI	F	1.10	1.20	1.99	1.97	0.89	0.87
Madison	WI	F	1.21	1.55	1.92	1.89	0.71	0.68
Sheboygan	WI	F	1.21	2.19	2.42	2.37	1.21	1.16
Superior	WI	F	1.14	1.50	2.03	1.99	0.89	0.85
Waukesha	WI	F	1.28	1.82	2.16	2.12	0.88	0.84
Wausau	WI	F	1.04	1.44	1.84	1.82	0.80	0.78
Charleston	WV	F	2.19	3.99	2.55	2.56	0.36	0.37
Clarksburg	WV	F	2.00	4.04	2.43	2.44	0.43	0.44
Cheyenne	WY	U		4.48	1.89	1.84		

Table 1. (Continued)

City	State	F/S/U[1]	"Class I Differentials, $/cwt." Actual 1995	Eau Claire plus TC[2]	Revenue-Adjusted May '95	Oct '95	Differences Revenue-Adj'd - Actual May '95	Oct '95
Minimum:			1.04	1.07	1.45	1.37	-1.72	-1.49
Maximum:			4.18	9.37	5.08	5.36	1.21	1.28
Weighted Average:[3]			2.49	5.22	2.47	2.47	-0.02	-0.03
Weighted Standard Deviation:			0.76	2.12	0.63	0.72	0.51	0.54
Count:			240	240	236	239	235	238
Differences = 0:							0	1
Differences < 0:							118	110
Differences > 0:							117	127

[1] F/S/U indicates regulatory status of the plant: F = federal regulation, S = state regulation, U = Unregulated.

[2] Eau Claire plus TC = Eau Claire plus raw milk assembly transportation cost centered on Minneapolis at $1.20. TC: $/cwt. = $0.004*MILES_{i,j}*(80{,}000/GVW_{i,j})*(0.65 + 0.35*WI_i)$ where GVW (gross vehicle weight) = 80,000 and WI (wage index) = 0.91 for all routes originating in Eau Claire. See J. Pratt et al., "A Description of the Methods and Data Employed in the U.S. Dairy Sector Simulator, Version 97.3," R.B. 97-09, Dept. of ARME, Cornell Univ., Ithaca, NY, July, 1997.

[3] Weighted average class I differentials for 'Actual 1995' and 'Eau Claire plus TC' use quantity of fluid milk processed in the May 1995 solution as weights. The May and October revenue-adjusted class I differentials are calculated by adding a constant to the shadow prices such that the class I revenue actually generated in those months is held constant.

Table 2. Simulated Differential Values at Manufacturing Plants, $/cwt.

City	State	Class II May	Class II October	Cheese May	Cheese October	Butter/Powder May	Butter/Powder October
Anniston	AL	1.52	1.07				
Birmingham	AL	1.52	1.07				
Greensboro	AL	1.56	1.11				
Montgomery	AL	1.56	1.12				
Batesville	AR	1.49	1.06				
Conway	AR	1.47	1.05				
Fayetteville	AR			0.92	0.76		
Fort Smith	AR	1.15	0.97				
Phoenix	AZ	0.74	0.58	0.75	0.58	0.72	0.23
Bakersfield	CA	0.38	0.15				
Chico	CA				0.34		
Corona	CA	0.62	0.39	0.63	0.40	0.54	0.17
Eureka	CA			0.51	0.21	0.49	0.12
Fresno	CA					0.49	0.13
Hanford	CA			0.53	0.32		
Lodi	CA	0.55	0.11				
Los Angeles	CA	0.80	0.58			0.57	0.19
Merced	CA			0.51	0.32	0.49	0.13
Modesto	CA	0.50	0.29	0.52	0.29	0.49	0.13
Salinas	CA	1.06	0.74				
San Francisco	CA	0.94	0.49			0.59	0.15
Santa Barbara	CA	1.09	0.77				
Tulare	CA	0.52		0.54	0.33		
Visalia	CA	0.61	0.32			0.49	0.13
Denver	CO	0.76	0.60	0.77	0.60		
Bridgeport	CT	1.58	1.15				
Hartford	CT	1.47	1.03				
Dover	DE	1.44	1.13				
Deerfield Beach	FL	1.76	1.32				
Tampa	FL	1.72	1.28				
Atlanta	GA	1.51	1.07				
Columbus	GA	1.54	1.10				
Des Moines	IA	1.13	0.81				
Elkader	IA			0.74	0.58	0.72	0.29
Le Mars	IA	0.88	0.68				
Oskaloosa	IA			0.79	0.63		
Sioux Center	IA			0.77	0.59	0.69	0.26
Waterloo	IA	1.05	0.57			0.72	0.27
Boise	ID	0.55	0.36				
Coeur d'Alene	ID				0.31		
Jerome	ID			0.51	0.34	0.49	0.14
Nampa	ID			0.51	0.31	0.49	0.12
Shelley	ID	0.53	0.36	0.54	0.37		
Carlyle	IL	1.14	0.95				
Chicago	IL	1.31	0.88				
Decatur	IL	1.23	0.96				
Forreston	IL	0.89	0.74				
Marion	IL	1.36	1.03				
Mount Carroll	IL					0.77	0.34
Quincy	IL	0.95	0.77				

Table 2. (Continued)

City	State	Class II		Cheese		Butter/Powder	
		May	October	May	October	May	October
Rockford	IL	0.95	0.72			0.78	0.35
Springfield	IL	1.37	0.97				
Gary	IN	1.15	0.85				
Goshen	IN			0.94	0.77	0.80	0.41
Indianapolis	IN	1.17	0.95				
Muncie	IN	1.07	0.95				
Chanute	KS			0.90	0.72		
Topeka	KS			0.94	0.74	0.80	0.40
Wichita	KS	0.91	0.71				
Louisville	KY					0.89	0.47
Owensboro	KY	1.30	1.01				
Springfield	KY					0.91	0.49
Franklinton	LA					0.99	0.56
Lake Charles	LA	1.58	1.09				
Monroe	LA	1.54	1.04				
New Orleans	LA	1.49	1.05				
Boston	MA	1.57	1.13				
Springfield	MA	1.40	0.97			1.07	0.67
Baltimore	MD	1.19	0.99				
Frederick	MD	1.12	0.96	1.13	0.96		
Laurel	MD					0.99	0.60
Portland	ME	1.49	1.26				
Waterville	ME			1.14	0.98		
Adrian	MI	1.11	0.79			0.80	0.45
Allegan	MI					0.76	0.43
Allendale	MI			0.95	0.77		
Benton Harbor	MI	0.99	0.83				
Detroit	MI	1.03	0.87		0.87	0.78	0.45
Jackson	MI			0.99	0.82		
Kalamazoo	MI	0.84	0.68			0.78	0.44
Mount Pleasant	MI			0.95	0.78		
Remus	MI	1.00	0.84				
Sault Ste. Marie	MI			0.93	0.76		
Fergus Falls	MN			0.70	0.54		
Long Prairie	MN			0.72	0.55	0.61	0.23
Minneapolis	MN	0.82	0.66				
Mora	MN					0.53	0.23
Rochester	MN	0.71	0.57	0.74	0.58	0.70	0.26
Saint Cloud	MN			0.73	0.57	0.68	0.28
Sauk Centre	MN					0.63	0.23
Slayton	MN	0.71	0.55	0.73	0.57		
Waconia	MN			0.72	0.55		
Cassville	MO			0.88	0.73		
Joplin	MO	1.07	0.89				
Kansas City	MO	1.09	0.86				
Marshfield	MO	0.87	0.71	0.88	0.72		
Saint Louis	MO	1.32	1.02			0.60	0.32
Sikeston	MO	1.43	1.05				
Springfield	MO					0.88	0.43

Table 2. (Continued)

City	State	Class II		Cheese		Butter/Powder	
		May	October	May	October	May	October
Decatur	MS	1.57	1.13				
Glendive	MT			0.62	0.46		
Greenville	NC	1.58	1.19				
Bismarck	ND			0.60	0.43	0.56	0.18
Dickinson	ND			0.57	0.40		
Granville	ND			0.61	0.45		
Grand Island	NE			0.81	0.64		
Norfolk	NE	0.77	0.60	0.79	0.62		
Omaha	NE					0.56	0.25
Randolph	NE			0.77	0.60		
Franconia	NH	1.34	1.15				
Manchester	NH	1.62	1.22				
Albuquerque	NM	1.32	0.96				
Las Cruces	NM			0.80	0.61		
Portales	NM			0.80	0.62	0.80	0.31
Adams	NY			1.05	0.89		
Batavia	NY		0.81			0.96	0.58
Bath	NY	0.93	0.78				
Binghamton	NY	0.95	0.81				
Buffalo	NY	1.02	0.86	1.04	0.87		
Canton	NY			1.03	0.87		
Delhi	NY	1.00	0.85				
Elmira	NY			1.08	0.92		
Friendship	NY			1.05	0.89		
Glens Falls	NY	1.26	1.10				
Goshen	NY	1.38	1.23				
Jamestown	NY	0.80	0.66				
New York	NY	1.63	1.25				
Rochester	NY			1.05	0.88		
Syracuse	NY	0.92	0.78				
Utica	NY	1.07	0.91	1.09	0.93		
Warsaw	NY	0.88					
Watertown	NY	0.98	0.83				
Brewster	OH	0.98	0.84	1.00	0.85		
Greenville	OH	0.82	0.74				
Minerva	OH	1.05	0.91				
Ottawa	OH					0.80	0.41
Saint Marys	OH	1.02	0.85				
Chickasha	OK			0.95	0.77		
Oklahoma City	OK	1.07	0.89				
Tulsa	OK	1.09	0.90				
Aumsville	OR		0.12			0.49	0.12
Coquille	OR	0.52	0.31	0.53	0.31		
Eugene	OR	0.74	0.37				
Portland	OR	0.57	0.31			0.49	0.07
Carlisle	PA					1.00	0.61
Chambersburg	PA	0.92	0.79				
Greensburg	PA			1.06	0.90		
Harrisburg	PA	1.09	0.93	1.11	0.93		

Table 2. (Continued)

City	State	Class II		Cheese		Butter/Powder	
		May	October	May	October	May	October
Johnstown	PA					0.92	0.54
Lancaster	PA	1.11	0.95	1.13	0.96	1.04	0.64
New Wilmington	PA	1.01	0.85	1.02	0.86		
Philadelphia	PA	1.38	1.11				
Reading	PA	1.15	1.00			1.06	0.66
State College	PA					0.67	0.37
Wellsboro	PA	1.02	0.86	1.04	0.88		
Providence	RI	1.59	1.16				
Charleston	SC	1.60	1.18				
Greenville	SC	1.51	1.11				
Bridgewater	SD			0.75	0.57	0.67	0.24
Eureka	SD			0.71	0.53	0.64	0.22
Sioux Falls	SD	0.82	0.66				
Watertown	SD			0.72	0.55		
Greeneville	TN	1.27	1.08				
Memphis	TN	1.47	1.04				
Nashville	TN	1.26	1.02				
Brownsville	TX	1.57	1.12				
Bryan	TX	1.52	1.03				
Dallas	TX	1.32	0.92				
Houston	TX	1.53	1.04				
Navasota	TX		1.04				
Stephenville	TX			0.94	0.76		
Sulphur Springs	TX	1.01	0.83			0.91	0.45
Ephraim	UT			0.58	0.41		
Ogden	UT			0.59	0.42		
Provo	UT	0.61	0.44	0.62	0.45		
Richmond	UT	0.35	0.19				
Salt Lake City	UT	0.72	0.56				
Bennington	VT	1.36	1.14				
Hinesburg	VT	1.30	0.98				
Newport	VT	1.05	0.91	1.08	0.92		
Saint Albans	VT					0.98	0.59
Swanton	VT			1.11	0.94		
Bellingham	WA			0.45	0.23		
Centralia	WA			0.47	0.29		
Lynden	WA					0.49	0.12
Seattle	WA	0.65	0.40			0.49	0.04
Spokane	WA					0.49	0.08
Sumner	WA	0.50	0.26		0.26		
Sunnyside	WA			0.43	0.24		
Appleton	WI	0.73	0.60	0.77	0.61	0.73	0.30
Arpin	WI					0.69	0.28
Baldwin	WI	0.71	0.57	0.75	0.58		
Barron	WI			0.75	0.59	0.69	0.26
Beaver Dam	WI			0.76	0.61		
Belgium	WI	1.12	0.79				
Boscobel	WI	0.83					
Chippewa Falls	WI			0.76	0.59	0.68	0.25

Table 2. (Continued)

City	State	Class II		Cheese		Butter/Powder	
		May	October	May	October	May	October
Darlington	WI			0.77	0.61		
Eau Claire	WI					0.70	0.27
Green Bay	WI	0.84	0.66			0.70	0.28
Greenwood	WI			0.76	0.60	0.54	0.24
Lancaster	WI			0.75	0.60		
Madison	WI	0.77	0.64	0.80	0.64	0.73	0.30
Manitowoc	WI	0.73		0.77	0.61		0.25
Menomonie	WI			0.76	0.59	0.67	0.26
Milwaukee	WI					0.79	0.36
Monroe	WI			0.79	0.63	0.70	0.27
Reedsburg	WI					0.66	0.24
Shawano	WI			0.74	0.58		
Tomah	WI			0.73	0.57		
Viroqua	WI	0.69	0.56	0.73	0.57		
Wausau	WI	0.69	0.55	0.72	0.57		
West Bend	WI					0.76	0.33
Whitehall	WI			0.76	0.60		
Martinsburg	WV	1.00	0.90				
Afton	WY			0.55	0.38		
Lander	WY					0.52	0.16
	Count:	129	128	86	90	67	68
	Minimum:	0.35	0.11	0.43	0.21	0.49	0.04
	Maximum:	1.76	1.32	1.14	0.98	1.07	0.67

Table 3. 1995 Location Values for Raw Milk at Supply Points ($/cwt.@3.5/8.62%)

City	State	May	October	City	State	May	October
Greensboro	AL	1.95	2.08	Quincy	IL	1.24	1.12
Hartselle	AL	1.70	1.84	Watseka	IL	1.28	1.14
Mobile	AL	2.59	2.70	Woodstock	IL	1.43	1.30
Montgomery	AL	2.23	2.36	Greencastle	IN	1.39	1.31
Arkadelphia	AR	1.62	1.51	Jasper	IN	1.46	1.40
Conway	AR	1.70	1.58	New Castle	IN	1.34	1.27
El Dorado	AR	1.85	1.71	Reynolds	IN	1.26	1.18
Fayetteville	AR	1.28	1.14	Scottsburg	IN	1.32	1.24
Phoenix	AZ	1.18	1.02	Warsaw	IN	1.27	1.13
Prescott	AZ	0.99	0.78	Chanute	KS	1.23	1.09
Safford	AZ	0.72	0.57	Dodge City	KS	0.73	0.58
Bakersfield	CA	0.79	0.60	Hoxie	KS	0.46	0.00
Chico	CA	1.02	0.71	Lincoln	KS	0.81	0.66
Corona	CA	1.05	0.86	Seneca	KS	1.12	0.96
Eureka	CA	0.93	0.69	Wichita	KS	1.25	1.09
Fresno	CA	0.93	0.62	Flemingsburg	KY	1.23	1.16
Hanford	CA	0.94	0.77	Glasgow	KY	1.26	1.40
Lodi	CA	0.96	0.59	Princeton	KY	1.56	1.46
Merced	CA	0.94	0.78	Shelbyville	KY	1.30	1.24
Modesto	CA	0.95	0.76	Somerset	KY	1.39	1.49
Ontario	CA	1.04	0.86	Kentwood	LA	2.02	2.15
Petaluma	CA	1.19	0.80	Lafayette	LA	2.39	2.27
Tulare	CA	0.96	0.78	Mansfield	LA	1.65	1.56
Colorado Springs	CO	1.14	1.00	Winnsboro	LA	2.08	2.01
Grand Junction	CO	1.46	1.31	Northampton	MA	1.96	1.82
Greeley	CO	0.86	0.73	Chestertown	MD	1.40	1.26
Hartford	CT	2.02	1.88	Frederick	MD	1.50	1.37
Dover	DE	1.76	1.61	Oakland	MD	1.34	1.26
Branford	FL	2.65	2.91	East Corinth	ME	1.18	1.06
Callahan	FL	2.68	2.86	Waterville	ME	1.38	1.26
Marianna	FL	2.37	2.64	Allegan	MI	1.20	1.07
Okeechobee	FL	2.97	3.12	Ann Arbor	MI	1.25	1.13
Zephyrhills	FL	3.01	3.26	Gaylord	MI	0.92	0.80
Blackshear	GA	2.49	2.65	Iron Mountain	MI	0.87	0.71
Eatonton	GA	1.85	1.99	Mount Pleasant	MI	1.29	1.16
Gainesville	GA	1.96	2.09	Sandusky	MI	1.15	1.03
Millen	GA	2.10	2.27	Sault Ste. Marie	MI	1.17	1.05
Moultrie	GA	2.20	2.49	Fergus Falls	MN	1.09	0.95
Elkader	IA	1.17	1.03	Long Prairie	MN	1.14	1.00
Greenfield	IA	1.20	1.09	Mora	MN	0.97	0.85
Oskaloosa	IA	1.15	1.01	Rochester	MN	1.17	1.02
Sioux Center	IA	1.19	1.03	Sauk Centre	MN	1.06	0.93
Coeur d'Alene	ID	1.00	0.75	Slayton	MN	1.11	0.96
Jerome	ID	0.95	0.80	Thief River Falls	MN	0.68	0.52
Montpelier	ID	0.65	0.52	Waconia	MN	1.09	0.94
Nampa	ID	0.93	0.77	Cameron	MO	1.28	1.12
Shelley	ID	0.89	0.75	Cassville	MO	1.28	1.15
Carlyle	IL	1.47	1.32	Clinton	MO	1.27	1.10
Effingham	IL	1.26	1.13	Marshfield	MO	1.30	1.16
Freeport	IL	1.24	1.11	Montgomery City	MO	1.38	1.24
Mount Carroll	IL	1.24	1.11	Palmyra	MO	1.21	1.08

Table 3. (Continued)

City	State	May	October	City	State	May	October
Perryville	MO	1.57	1.49	Wooster	OH	1.28	1.15
Coldwater	MS	2.06	1.94	Zanesville	OH	1.31	1.19
Decatur	MS	2.03	2.16	Atoka	OK	1.14	0.99
McComb	MS	2.05	2.18	Cheyenne	OK	0.89	0.73
West Point	MS	2.13	2.29	Chickasha	OK	1.20	1.04
Billings	MT	1.01	1.03	Lawton	OK	1.09	0.94
Bozeman	MT	0.67	0.69	Pryor	OK	1.31	1.15
Glendive	MT	0.95	0.82	Stillwater	OK	1.14	0.98
Great Falls	MT	1.11	1.12	Aumsville	OR	0.93	0.62
Hamilton	MT	1.11	1.15	Coquille	OR	0.86	0.68
Miles City	MT	0.80	0.66	Gilchrist	OR	0.81	0.50
Ronan	MT	0.85	0.89	Ironside	OR	0.60	0.00
Asheville	NC	1.65	1.74	Timber	OR	0.87	0.65
Fayetteville	NC	1.94	2.09	Chambersburg	PA	1.35	1.25
Statesville	NC	1.55	1.74	Greensburg	PA	1.44	1.31
West Hillsborough	NC	1.83	1.99	Lancaster	PA	1.54	1.40
Bismarck	ND	1.02	0.88	Lewistown	PA	1.29	1.16
Dickinson	ND	0.95	0.82	Meadville	PA	1.19	1.06
Granville	ND	0.98	0.84	Reading	PA	1.58	1.44
Lisbon	ND	0.65	0.00	Towanda	PA	1.28	1.15
Minnewaukan	ND	0.69	0.58	Tunkhannock	PA	1.44	1.31
Stanley	ND	0.76	0.63	Wellsboro	PA	1.38	1.25
Ansley	NE	0.93	0.81	Providence	RI	2.24	2.10
Beatrice	NE	1.23	1.10	Newberry	SC	1.78	1.94
O'Neill	NE	0.87	0.74	Orangeburg	SC	2.02	2.19
Randolph	NE	1.14	0.99	Sumter	SC	1.94	2.10
Scottsbluff	NE	0.57	0.00	Bridgewater	SD	1.17	1.02
Concord	NH	1.91	1.77	Eureka	SD	1.13	0.98
Franconia	NH	1.64	1.52	Gregory	SD	0.71	0.57
Glassboro	NJ	1.64	1.49	Newell	SD	0.58	0.64
Hackettstown	NJ	1.78	1.63	Rapid City	SD	0.81	0.86
Albuquerque	NM	1.67	1.48	Watertown	SD	1.09	0.94
Las Cruces	NM	1.05	0.88	Dresden	TN	1.71	1.61
Portales	NM	1.23	1.06	Greeneville	TN	1.50	1.59
Fallon	NV	0.56	0.00	Lewisburg	TN	1.50	1.66
Jean	NV	1.56	1.36	McMinnville	TN	1.64	1.79
Bath	NY	1.36	1.22	Alto	TX	1.82	1.64
Canton	NY	1.38	1.24	Decatur	TX	1.41	1.24
Cortland	NY	1.19	1.08	Dimmitt	TX	1.26	1.09
Delhi	NY	1.36	1.24	El Paso	TX	1.18	1.01
Geneseo	NY	1.36	1.23	Gilmer	TX	1.58	1.41
Goshen	NY	1.77	1.64	Navasota	TX	2.01	1.83
Jamestown	NY	1.23	1.09	San Angelo	TX	1.14	0.98
Plattsburgh	NY	1.34	1.20	San Diego	TX	2.08	1.91
Utica	NY	1.43	1.29	Stephenville	TX	1.26	1.10
Warsaw	NY	1.33	1.20	Sulphur Springs	TX	1.43	1.27
Watertown	NY	1.34	1.20	Ephraim	UT	0.85	0.71
Greenville	OH	1.21	1.14	Provo	UT	0.91	0.77
Jefferson	OH	1.33	1.21	Richmond	UT	0.71	0.59
Ottawa	OH	1.24	1.10	Abingdon	VA	1.50	1.61
West Union	OH	1.22	1.14	Blackstone	VA	1.46	1.63

Table 3. (Continued)

City	State	May	October
Harrisonburg	VA	1.33	1.43
Richmond	VA	1.70	1.78
Rocky Mount	VA	1.40	1.56
Newport	VT	1.44	1.31
Rutland	VT	1.56	1.44
Bellingham	WA	0.88	0.70
Centralia	WA	0.87	0.70
Deer Park	WA	0.85	0.60
Sedro-Woolley	WA	0.83	0.62
Sumner	WA	0.91	0.70
Sunnyside	WA	0.79	0.63
Appleton	WI	1.19	1.05
Baldwin	WI	1.15	1.01
Barron	WI	1.18	1.04
Beaver Dam	WI	1.17	1.03
Chippewa Falls	WI	1.19	1.04
Darlington	WI	1.18	1.04
Fond du Lac	WI	1.14	1.01
Greenwood	WI	1.16	1.04
Lancaster	WI	1.14	1.00
Madison	WI	1.22	1.08
Manitowoc	WI	1.17	1.05
Menomonie	WI	1.18	1.04
Monroe	WI	1.22	1.07
Shawano	WI	1.14	1.00
Tomah	WI	1.12	0.98
Viroqua	WI	1.10	0.97
Wausau	WI	1.11	0.98
Whitehall	WI	1.16	1.02
Clarksburg	WV	1.56	1.48
Lewisburg	WV	1.30	1.30
Martinsburg	WV	1.39	1.31
Point Pleasant	WV	1.43	1.34
Afton	WY	0.89	0.75
Guernsey	WY	0.77	0.64
Sheridan	WY	0.65	0.68
	Minimum:	0.46	0.00
	Maximum	3.01	3.26
	Weighted Average:	1.23	1.09
	Count:	240	240

Table 4. USDSS-Generated Revenue-Adjusted Differentials: 1960 Supply Distribution with 1960-1990 Population Distributions for Ten Selected Cities

Rank	1960	1965	1970	1975	1980	1985	1990	1995	OCT. '95 BASE SOLUTION
1	LA 3.18	Phoenix 3.81	Phoenix 3.81	Miami 4.64	Miami 4.71	Miami 4.80	Miami 5.05	Miami 5.05	Miami 5.36
2	Boston 3.12	Miami 3.61	Miami 3.77	Phoenix 4.31	Phoenix 4.38	Phoenix 4.41	Phoenix 4.67	Phoenix 4.69	Atlanta 3.52
3	Miami 3.03	LA 3.17	LA 3.17	LA 3.15	LA 3.22	LA 3.24	LA 3.50	LA 3.52	Boston 3.05
4	Phoenix 3.01	Boston 3.09	Boston 3.07	Boston 2.99	Atlanta 3.00	Atlanta 2.99	Atlanta 2.99	Atlanta 2.98	NYC 2.73
5	Atlanta 2.99	Atlanta 2.97	Atlanta 2.96	Atlanta 2.92	Boston 2.93	Boston 2.86	Dallas 2.83	Dallas 2.91	Chicago 2.41
6	NYC 2.93	NYC 2.89	NYC 2.87	NYC 2.76	Dallas 2.74	Dallas 2.85	Boston 2.82	Boston 2.76	Dallas 2.40
7	Dallas 2.73	Dallas 2.71	Dallas 2.72	Dallas 2.66	NYC 2.70	NYC 2.64	Seattle 2.61	Seattle 2.62	Minn. 1.93
8	Seattle 2.69	Seattle 2.67	Seattle 2.68	Seattle 2.66	Seattle 2.65	Seattle 2.62	NYC 2.60	NYC 2.54	Phoenix 1.85
9	Chicago 2.56	Chicago 2.53	Chicago 2.52	Chicago 2.45	Chicago 2.41	Chicago 2.36	Chicago 2.34	Chicago 2.33	LA 1.84
10	Minn. 2.14	Minn. 2.10	Minn. 2.10	Minn. 2.03	Minn. 2.00	Minn. 1.96	Minn. 1.96	Minn. 1.96	Seattle 1.67
Highest	Corpus Christi 3.77	Yuma 4.05	Yuma 4.05	Miami 4.64	Miami 4.71	Miami 4.80	Miami 5.05	Miami 5.05	Miami 5.36
Lowest	Thief River Falls 1.78	= 1.75	= 1.74	= 1.68	= 1.64	= 1.60	= 1.59	= 1.58	= 1.37

Table 5. Ratio of Milk Supply to Population Shares for Three States Using Three Combinations of Years

	1960 Supply 1960 Demand	1960 Supply 1995 Demand	1995 Supply 1995 Demand
Florida	.41	.21	.28
California	.76	.55	1.35
Arizona	.54	.24	.89

Table 6. USDSS-Generated Revenue-Adjusted Differentials: 1995 Supply Distribution with 2000-2025 Projected Population Distributions for Ten Selected Cities

RANK	OCT. BASE	2000	2005	2015	2025
1	Miami 5.36	Miami 5.20	Miami 5.29	Miami 5.27	Miami 5.25
2	Atlanta 3.52	Atlanta 3.36	Atlanta 3.42	Atlanta 3.41	Atlanta 3.40
3	Boston 3.05	Boston 3.05	Boston 3.01	Boston 2.95	Boston 2.94
4	NYC 2.73	NYC 2.73	NYC 2.69	NYC 2.63	NYC 2.62
5	Chicago 2.41	Dallas 2.46	Dallas 2.46	Dallas 2.48	Dallas 2.49
6	Dallas 2.40	Chicago 2.43	Chicago 2.40	Chicago 2.36	LA 2.46
7	Minn. 1.93	Minn. 1.94	LA 1.94	LA 2.30	Chicago 2.35
8	Phoenix 1.85	LA 1.94	Minn. 1.93	Phoenix 1.99	Phoenix 2.05
9	LA 1.84	Phoenix 1.91	Phoenix 1.91	Seattle 1.95	Seattle 1.99
10	Seattle 1.67	Seattle 1.79	Seattle 1.85	Minn. 1.91	Minn. 1.91
Highest	Miami 5.36	= 5.20	= 5.29	= 5.27	= 5.25
Lowest	Thief River Falls 1.37	= 1.42	= 1.42	= 1.48	= 1.51

Table 7. USDSS Model-Generated Revenue-Adjusted Differentials for the Base and Minimum Fluid Throughput Scenarios.

CITY	NODE	RNDIFF	MIN_THRU	Difference
Birmingham	AL	2.957	2.893	-0.06
Dothan	AL	3.637	3.616	-0.02
Huntsville	AL	2.609	2.546	-0.06
Mobile	AL	3.625	3.389	-0.24
Montgomery	AL	3.301	3.229	-0.07
Fayetteville	AR	2.066	2.188	0.12
Fort Smith	AR	2.295	2.416	0.12
Little Rock	AR	2.728	3.002	0.27
Phoenix	AZ	1.884	1.885	0.00
Yuma	AZ	2.464	2.465	0.00
Fresno	CA	1.64	1.638	0.00
Los Angeles	CA	1.949	1.949	0.00
Merced	CA	1.64	1.638	0.00
Modesto	CA	1.651	1.649	0.00
Redding	CA	2.132	1.991	-0.14
Salinas	CA	2.549	2.547	0.00
San Diego	CA	2.157	2.156	0.00
San Francisco	CA	2.092	2.091	0.00
Santa Barbara	CA	2.25	2.249	0.00
Visalia	CA	1.758	1.754	0.00
Colorado Springs	CO	2.13	2.139	0.01
Denver	CO	1.907	1.916	0.01
Fort Collins	CO	1.843	1.852	0.01
Grand Junction	CO	2.536	2.238	-0.30
Greeley	CO	1.73	1.739	0.01
Bridgeport	CT	3.011	2.94	-0.07
Hartford	CT	2.839	2.713	-0.13
Dover	DE	2.588	2.525	-0.06
Deerfield Beach	FL	4.954	5.063	0.11
Jacksonville	FL	4.126	3.925	-0.20
Lakeland	FL	4.561	4.543	-0.02
Miami	FL	5.079	5.189	0.11
Orlando	FL	4.505	4.487	-0.02
Tampa	FL	4.574	4.554	-0.02
Athens	GA	3.167	2.915	-0.25
Atlanta	GA	3.255	3.003	-0.25
Columbus	GA	3.466	3.227	-0.24
Macon	GA	3.139	2.887	-0.25
Savannah	GA	3.634	3.416	-0.22
Cedar Rapids	IA	2.336	2.345	0.01
Des Moines	IA	2.274	2.285	0.01
Dubuque	IA	2.005	2.014	0.01
Iowa City	IA	2.266	2.277	0.01
Le Mars	IA	2.028	2.034	0.01
Boise	ID	1.694	1.692	0.00
Pocatello	ID	1.747	1.752	0.00
Bloomington	IL	2.559	2.741	0.18
Champaign	IL	2.371	2.557	0.19
Chicago	IL	2.461	2.423	-0.04
East Saint Louis	IL	2.456	2.445	-0.01

Table 7. (Continued)

CITY	NODE	RNDIFF	MIN_THRU	Difference
Moline	IL	2.326	2.315	-0.01
Olney	IL	2.249	2.435	0.19
Peoria	IL	2.647	2.635	-0.01
Quincy	IL	2.096	2.085	-0.01
Rockford	IL	2.095	2.058	-0.04
Evansville	IN	2.439	2.608	0.17
Fort Wayne	IN	2.12	2.129	0.01
Gary	IN	2.299	2.308	0.01
Holland	IN	2.332	2.502	0.17
Indianapolis	IN	2.316	2.356	0.04
Muncie	IN	2.221	2.261	0.04
Rochester	IN	2.162	2.171	0.01
Wichita	KS	2.053	1.883	-0.17
London	KY	2.297	2.506	0.21
Louisville	KY	2.154	2.172	0.02
Murray	KY	2.638	2.649	0.01
Somerset	KY	2.16	2.369	0.21
Winchester	KY	2.282	2.3	0.02
Baton Rouge	LA	3.167	3.058	-0.11
Lafayette	LA	3.38	3.27	-0.11
Monroe	LA	3.124	3.161	0.04
New Orleans	LA	3.188	3.078	-0.11
Shreveport	LA	2.712	2.773	0.06
Boston	MA	3.089	3.034	-0.06
Springfield	MA	2.781	2.766	-0.02
Baltimore	MD	2.335	2.344	0.01
Cumberland	MD	2.384	2.133	-0.25
Frederick	MD	2.263	2.264	0.00
Bangor	ME	2.144	2.193	0.05
Lewiston	ME	2.491	2.54	0.05
Portland	ME	2.638	2.687	0.05
Detroit	MI	2.179	2.174	0.00
Evart	MI	2.117	2.243	0.13
Gaylord	MI	1.695	1.819	0.12
Grand Rapids	MI	2.03	2.045	0.02
Iron Mountain	MI	1.598	1.604	0.01
Jackson	MI	2.128	2.124	0.00
Kalamazoo	MI	1.989	2.004	0.01
Lansing	MI	2.229	2.244	0.02
Livonia	MI	2.086	2.082	0.00
Saginaw	MI	2.089	2.084	0.00
Sault Ste. Marie	MI	2.059	2.024	-0.04
Duluth	MN	2.015	2.021	0.01
Minneapolis	MN	1.972	1.978	0.01
Rochester	MN	1.859	1.866	0.01
Sauk Centre	MN	1.774	1.779	0.00
Thief River Falls	MN	1.453	1.437	-0.02
Cassville	MO	2.02	2.04	0.02
Columbia	MO	2.365	2.342	-0.02
Kansas City	MO	2.233	2.195	-0.04

Table 7. (Continued)

CITY	NODE	RNDIFF	MIN_THRU	Difference
Springfield	MO	2.085	2.098	0.01
Saint Louis	MO	2.464	2.453	-0.01
Jackson	MS	3.215	2.976	-0.24
West Point	MS	3.147	2.943	-0.20
Billings	MT	1.923	2.359	0.44
Bozeman	MT	1.525	2.327	0.80
Great Falls	MT	2.109	2.494	0.39
Hamilton	MT	1.996	1.819	-0.18
Asheville	NC	2.638	2.847	0.21
Charlotte	NC	2.64	2.958	0.32
Dunn	NC	3.021	3.338	0.32
Goldsboro	NC	3.087	3.405	0.32
High Point	NC	2.718	3.036	0.32
Kinston	NC	3.196	3.513	0.32
Raleigh	NC	2.887	3.2	0.31
Bismarck	ND	1.73	1.735	0.01
Fargo	ND	1.63	1.59	-0.04
Grand Forks	ND	1.799	1.783	-0.02
Lincoln	NE	2.17	2.209	0.04
Omaha	NE	2.356	2.396	0.04
Randolph	NE	1.892	1.904	0.01
Concord	NH	2.808	2.745	-0.06
Franconia	NH	2.49	2.428	-0.06
Florence	NJ	2.652	2.657	0.00
Newark	NJ	2.764	2.775	0.01
Trenton	NJ	2.709	2.715	0.01
Wallington	NJ	2.793	2.804	0.01
Albuquerque	NM	2.636	2.637	0.00
Santa Fe	NM	2.87	2.871	0.00
Las Vegas	NV	2.615	2.614	0.00
Reno	NV	1.567	1.574	0.01
Albany	NY	2.485	2.47	-0.01
Binghamton	NY	2.095	2.08	-0.02
Buffalo	NY	2.165	2.176	0.01
Glens Falls	NY	2.408	2.404	0.00
Jamestown	NY	1.953	1.964	0.01
New York	NY	2.774	2.759	-0.02
Rochester	NY	2.174	2.185	0.01
Syracuse	NY	2.073	2.058	-0.02
Utica	NY	2.218	2.229	0.01
Canton	OH	2.152	2.168	0.02
Cincinnati	OH	2.221	2.261	0.04
Cleveland	OH	2.335	2.284	-0.05
Columbus	OH	2.345	2.36	0.01
Marietta	OH	2.352	2.514	0.16
Steubenville	OH	2.401	2.416	0.02
Toledo	OH	2.176	2.173	0.00
Youngstown	OH	2.233	2.241	0.01
Oklahoma City	OK	2.223	2.22	0.00
Tulsa	OK	2.237	2.147	-0.09

Table 7. (Continued)

CITY	NODE	RNDIFF	MIN_THRU	Difference
Eugene	OR	1.89	1.888	0.00
Medford	OR	2.188	2.429	0.24
Portland	OR	1.717	1.833	0.12
Allentown	PA	2.431	2.491	0.06
Altoona	PA	2.298	2.303	0.00
Chambersburg	PA	2.069	2.077	0.01
Erie	PA	2.116	2.125	0.01
Harrisburg	PA	2.237	2.243	0.01
Johnstown	PA	2.382	2.391	0.01
Lancaster	PA	2.26	2.266	0.01
New Wilmington	PA	2.157	2.165	0.01
Philadelphia	PA	2.524	2.53	0.01
Pittsburgh	PA	2.288	2.297	0.01
Reading	PA	2.303	2.363	0.06
Scranton	PA	2.33	2.341	0.01
State College	PA	2.15	2.156	0.01
Williamsport	PA	2.344	2.35	0.01
Providence	RI	3.141	3.015	-0.13
Charleston	SC	3.454	3.773	0.32
Greenville	SC	2.867	3.075	0.21
Rapid City	SD	1.636	1.643	0.01
Sioux Falls	SD	1.967	1.973	0.01
Bristol	TN	2.493	2.728	0.24
Chattanooga	TN	2.869	2.752	-0.12
Kingsport	TN	2.581	2.816	0.24
Knoxville	TN	2.689	2.898	0.21
Memphis	TN	3.204	3.005	-0.20
Nashville	TN	2.413	2.519	0.11
Amarillo	TX	2.289	2.288	0.00
Austin	TX	2.674	2.666	-0.01
Bryan	TX	3.147	3.138	-0.01
Corpus Christi	TX	3.485	3.498	0.01
Dallas	TX	2.472	2.463	-0.01
Decatur	TX	2.228	2.219	-0.01
El Paso	TX	2.104	2.105	0.00
Houston	TX	3.287	3.277	-0.01
Lubbock	TX	2.379	2.378	0.00
San Antonio	TX	2.977	2.969	-0.01
Sulphur Springs	TX	2.161	2.152	-0.01
Tyler	TX	2.647	2.638	-0.01
Waco	TX	2.779	2.771	-0.01
Provo	UT	1.757	1.768	0.01
Saint George	UT	2.54	2.545	0.00
Salt Lake City	UT	1.873	1.884	0.01
Lynchburg	VA	2.486	2.726	0.24
Norfolk	VA	2.911	3.152	0.24
Richmond	VA	2.549	2.789	0.24
Roanoke	VA	2.376	2.694	0.32
Burlington	VT	2.39	2.385	-0.01
Rutland	VT	2.372	2.32	-0.05

Table 7. (Continued)

CITY	NODE	RNDIFF	MIN_THRU	Difference
Pasco	WA	1.721	1.731	0.01
Seattle	WA	1.794	1.766	-0.03
Sedro-Woolley	WA	1.555	1.527	-0.03
Spokane	WA	1.64	1.638	0.00
Appleton	WI	1.879	1.886	0.01
Green Bay	WI	1.988	1.995	0.01
La Crosse	WI	1.987	1.994	0.01
Madison	WI	1.92	1.928	0.01
Sheboygan	WI	2.415	2.379	-0.04
Superior	WI	2.034	2.04	0.01
Waukesha	WI	2.157	2.121	-0.04
Wausau	WI	1.835	1.842	0.01
Charleston	WV	2.546	2.564	0.02
Cheyenne	WY	1.885	1.895	0.01

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